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NOVEMBER 1956

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HOT-COLD WATER MIXER

A fool-proof water mixer that shuts itself off in case of failure of the thermostat motor is the description of this Type N Hydroguard valve by the Powers Regulator Company, Skokie, Ill. The mixer will also shut off the required port in case of hot or cold water supply failure. Unique features include rotating inlets and outlet which turn in 90 degree steps so that the mixer can be installed in any position. Temperature settings in the 65-115 or 85-160 degree F ranges are controlled by a concealed adjustment which can be locked to prevent tampering.

Accuracy of the mixer holds the water delivery temperature within plus or minus 2 degrees under any of these conditions: (1) A 75 per cent drop in inlet pressures; (2) A 45 degree fluctuation in hot water supply temperature; (3) An 85 per cent restriction of discharge flow.

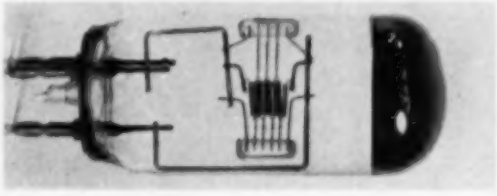
Other features of the N Hydroguard are: (1) Balanced valves, which provide positive shut off by contact between self-aligning bronze poppets and valve seats. This eliminates stem binding or water leakage present in sleeve or plunger type valves; (2) Integrally-built check valves. These prevent interchange of hot and cold water supplies. Spring loaded, they operate in any position; (3) Bronze strainers, which can be removed for cleaning without breaking pipe connections or removing unit from line; (4) Stop valves built into the mixer, which permit the unit to be serviced without shutting off main water supplies; (5) Easy maintenance. The Hydroguard can be completely dismantled without removing it from the line, using only standard wrenches. Check valve seats and poppets are also removable in the field.

Sold by plumbing wholesalers and jobbers, prices are $150 for the N-45 in rough bronze, and $210 in chrome plate. The N-125 is $225 in rough bronze and $300 in chrome plate. Shipping weights are 18 lbs. for the N-45 and 30 lbs. for the N-125.

Detailed information is in Bulletin 362, available from the Powers Regulator Company, 3434 Oakton St., Skokie, Ill., or from the Powers Regulator Company of Canada, Ltd., 15 Torbarrie Rd., Downsview, Ont.

USE OF CAMERA TRIPODS INCREASING

Sales figures on tripods indicate that their use is increasing sharply, according to the West German Camera Information Center. This is another part of the vast upgrading in technical competence and quality standards which has swept through American photography, both amateur and professional, since the war. The largest tripod production program in the world, that of the Linhof works in West Germany, has recently been enlarged with the addition of two inexpensive tripods for amateurs, the "Compact" and the "Featherweight." Both are "center column" devices with auxiliary columns available which are easily substituted to increase the camera height. The "Compact" weighs only 33 ounces, and extends from 17 to 42 inches, which makes it just right for reflex cameras. The "Featherweight" weighs 37 ounces and extends to 55 inches.



LYING DOWN, COOL LAMP

A new projection lamp developed by the General Electric Company, combines horizontal burning with a vertical filament and a baseless construction. These features make possible a lamp which (1) operates at cooler temperatures, (2) is precision-focused, (3) makes low-contour projector designs possible, and (4) ensures cost savings in projectors designed for its use. The lamp has a distinctive golden top, applied inside the envelope, which minimizes stray light. Shown above is the 500-watt version of the lamp which will also be available in the 300-watt size.

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Established in 1950, Photographic Science and Technique was prepared under the editorial management and control of the Technical Division of the Society until June 1, 1956. The first four volumes were issued as Section B of the PSA Journal and numbered 16B to 19B inclusively. As a separate publication, Series II, Volume 1, Number 1 started in the first quarter of 1954.

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ALARM SYSTEMS AND VISUAL AIDS APPLIED TO AUTOMATIC PROCESSING MACHINES

Ira R. Kohlman*

ABSTRACT

In order to minimize loss or damage to films automatically processed, alarm systems are a necessity. Flow raters, level indicators, temperature controllers, and various other devices are described.

FOR MANY YEARS, photographers preferred having their films processed by hand. The thought of films being processed by a large photofinishing company was synonymous with poor quality. However, and regrettably, there was a sound basis for this thinking. In fact, even today, a good technician can process a roll of color film, such as Anscochrome or Ektachrome, as well, if not better, than many color finishers. Obviously, the cost of hand processing and the time consumed would be much greater than current processing charges and service.

It is hardly necessary to state that automatic processing is becoming quite common. Inasmuch as this automatic equipment is used for customers' films which in most cases are irreplaceable, methods for minimizing film damage are desirable.

Various types of mechanical, electrical and electromechanical devices are used to control several phases of the process. These include the following:

1. The speed of the processing machine, which determines the immersion time of the films in the various chemical baths.
2. The temperatures of the solutions, which are important in determining the rates of reaction of the chemicals on the films.
3. The agitation, which determines the evenness of development and also affects developing time.
4. The replenishment, which keeps the various solutions at a pre-determined equilibrium by offsetting any decrease or increase of the chemical components of the various solutions by the film being processed through them.
5. The circulation, which aids temperature control and replenishment and contributes to agitation.
6. The filtration, which removes foreign matter from the solutions, thereby keeping films clean.

Failure or partial failure of any one of the devices used to control these functions can cause damage. Therefore, alarm systems and convenient methods of visually checking these devices become a necessity.

Machine Speed

The speed of a processing machine drive is not always indicative of the speed of the film traveling through the solutions. This is especially true of a continuous processing machine. To determine the speed of the film going through the processor, a simple method is to couple an FPM meter to one of the free rollers that are driven by the film passing over the rollers.

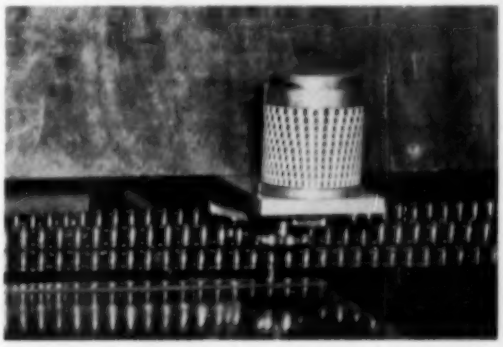

Fig. 1. Stroboscopic drum of the processing machine speed indicator. When viewed by pulsating light from a neon lamp, the row of segments which appears to be standing still indicates the speed of the machine.

With a rack-and-tank type processing machine, the rack transfer is directly proportional to the motor drive mechanism. Therefore, the speed can be determined from a drive chain. A unique method of indicating the speed of this type of machine is to couple a drum to a convenient drive chain. Around the drum is glued a strip of paper containing equal black and white segments drawn on the paper. By arranging these segments in the right size and quantity and then illuminating the drum with a neon lamp, a stroboscopic effect is obtained. The formula used to determine the number of equal segments required is 120 over the feet per second of the drive chain. The theory involved is based on the fact that a neon lamp being of the gaseous discharge type contains two electrodes which ignite the gas alternately 60 times a second or a total of 120 per second. Assuming of course, that the usual standard A.C. line current of 60 cycles per second is used. When these segments appear to be standing still while the drum is revolving, the desired speed is being maintained. However, when these segments are moving forward or in reverse, an increase or decrease in the speed of the machine is indicated.

* Pavelle Color Incorporated, 533 West 57th Street, New York 19, New York. Presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York 26 May, 1956. Received 14 June, 1956.

Fig. 2. Gas agitation alarm system actuates an audible signal when the pressure drops below a predetermined level, warning the operator of the need to switch to a new set of nitrogen tanks.

Temperature Control

According to manufacturers' recommendations and through practical experience, it was found that the temperature control of the developers should be maintained quite accurately. The developer temperature requirements of the various color films are as follows:

Anscochrome 68 F plus and minus $^1/_2$ degree F.
Ektachrome 75 F plus and minus $^1/_2$ degree F.
Kodachrome 80 F plus and minus $^1/_4$ degree F.
Kodacolor 75 F plus and minus $^1/_2$ degree F.

Therefore, equipment used to control temperature should be selected carefully. To correlate the results of processing and temperature control, it is desirable to have some sort of recording temperature control unit so that any processing fluctuations in the films can be checked against the recorded temperature of the critical solutions in which the films were immersed.

A typical electric alarm system that warns the operator of approaching danger of increasing or decreasing temperature of the critical solutions is one that utilizes an accurate dial thermometer containing two arms with contact points above and below the pointer. These contact points are made of silver. The contact arms may be set to the required plus and minus tolerances, which may be a half degree spread or greater. If the temperature reaches a value corresponding to either the high or low contact setting, the pointer touches the contact arm and energizes a relay. This will close the circuit to a light, bell, horn, solenoid or any other means of alarm selected.

Agitation

An important phase of film processing is agitation. To maintain even development and consistent speed of the film, agitation should be controlled. Various methods of agitation have been used in the past, however, the "new look" in agitation is the gas burst type. The use of compressed air and nitrogen delivered under pressure to pipes containing small orfices at the bottom of the processing tanks are employed. Nitrogen, rather than air, is used in developers so as to prevent oxidation. Continuous bubbling of the gas in the solutions forms a pattern and results in uneven development, therefore, short bursts of gas are used. An example of a cycle used is a two-second burst every ten seconds. An excellent instrument used to acquire any desired burst cycle is the Flex-o-pulse, manufactured by the Eagle Signal Corporation in Moline, Illinois. This instrument is adjustable to any burst cycle required and is operated on any standard line current.

One of the problems of gas agitation is maintaining the supply of nitrogen during processing. When a tank of nitrogen is exhausted, a new tank must be connected to the system as quickly as possible. If a tank runs dry and goes unnoticed, agitation ceases in the most critical solutions which may cause a photographic shift. To prevent this from occurring, a pressure valve can be placed in the system which will cause an alarm to signal when the pressure from the nitrogen supply tank drops below a pre-determined pressure. In the Pavelle laboratory system, the gas burst pressure is from 12 to 15 lbs per sq in. This pressure switch can be adjusted to give ample time for a new tank of gas to be installed before the gas in the current tank is exhausted.

Replenishment

Continuous replenishment systems have been in existence for some time in the motion picture processing industry. The replenishment rate of a given process is determined through photographic testing and chemical analysis. Film manufacturers, after running hundreds of tests, determine replenishment rates to be used for their products. In most cases, these rates can be used quite satisfactorily. Variations in processing machines, such as circulation rate, solution surface area and so on, may require slight adjustments in the rate of replenishment. After the rate has been ascertained, it is important to control it consistently.

Flow raters are employed to regulate the amount of replenisher fed into a solution. A flow rater is composed of a graduated glass cylinder, an inlet at the bottom of the cylinder and an outlet at the top. Inside the cylinder is located a stainless steel bob (or a float as the literature often refers to it). The float will rise indicating the rate of flow of fluid passing through the cylinder at a given time. A needle valve that may be incorporated as an integral part of the meter may be installed at either the inlet or outlet end of the flow rater and is used to adjust the flow of solution.

These flow raters can be supplied with alarm systems that provide as many as four individually adjustable alarm points. Attached to the float is an extension arm that extends through the top of the cylinder housing. Within the alarm assembly, which is located above the cylinder housing, individual magnetic switches are positioned at the alarm contact points desired. Each switch assembly includes a permanent magnet and a hermetically sealed magnetically actuated switch. When the float extension arm containing a soft iron core enters the field of the magnet and switch, the magnetic flux is diverted, releasing the spring loaded contact within the switch. This locked-in magnet arrangement, based on diverting rather than increasing the magnetic

flux, permits powerful and positive contact positioning, unaffected by vibration.

The iron core in the float extension arm is subjected to the magnetic field at only one small point of its circumference. This eliminates any hysteresis error in the float due to magnetic forces.

A method of replenishment currently used at Pavelle laboratories on a machine transferring racks of film rather than continuous lengths of film, is sometimes referred to as batch replenishment. Racks containing a uniform quantity of film are sent through the processing machine; at one position each rack trips a microswitch. The depressed microswitch actuates a timer which in turn opens a solenoid valve that permits a pre-determined quantity of replenisher to flow into the processing tank. This replenisher is contained in a calibrated sight glass. After the dump timer has completed its cycle, a second timer is actuated that refills the sight glass from a replenisher storage tank located above the processing machine. The second timer actuates another solenoid valve and sends the gravity-fed replenisher to the sight glass. It is a simple task to change the replenishing rate by adjusting the timer. Also, a convenient visual check is available by means of the calibrated sight glass.

Circulation

Circulation or recirculation of various chemical solutions provides a convenient means of continuous filtering, temperature control, adding replenisher and aids in the agitation of the solutions within the processing tanks. If a constant rate of circulation is not maintained, many things may be affected. For example, on certain processing machines, replenisher is introduced into a sump tank and the solution in the sump tank is then circulated through filters and then pumped to the processing machine tank. If there is a drop in the circulation system, a build-up of replenisher may occur in the sump tank and eventually go down the drain by way of an overflow line, and the processing tank solution will be under-replenished. Therefore, even though the replenishment rate is controlled with this circulation system there is a possibility of under-replenishing. The use of audible indicating flow meters located in strategic positions in the various circulation systems on a processing machine would be another means of assuring high quality.

The most common cause for decrease in circulation rate is a clogged filter. Pressure gauges are placed at the inlet and outlet of each filter or filter bank to indicate the pressure drop in the filter system. Where the pressure difference between inlet and outlet reaches a pre-established level, a filter change is indicated.

Level Indicators

Although the possibility is slight, a pipe in the circulation system may crack or a hole in a processing tank may develop or a valve may leak. If any of these mishaps occur in the darkroom section of a processing machine, many films can be ruined because of the low level of the solution. In order to prevent this, cylinders mounted outside the wall of the darkroom can be connected to the various tanks in the darkroom with flexible tubing or other connectors, so that the level of the solution in the processing tank is indicated in the cylinder outside the darkroom. A float with an extension arm is placed inside the cylinder, and when the float drops, a switch is hit which actuates the alarm.

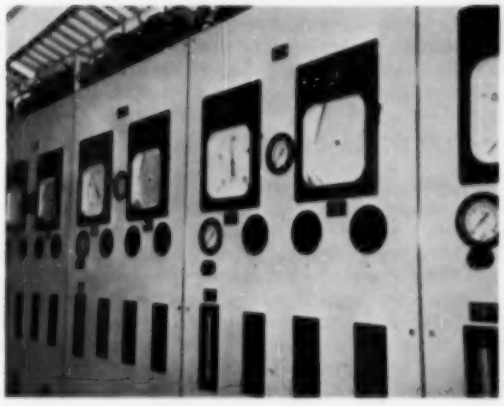

Fig. 3. Panel board for Kodachrome film processing machine, having eventual capacity to control four machines. Temperature recorders and indicators are mounted above and indicators below show recirculation rate, pump pressure, and replenishment rate.

Machine Film Break Alarms

An important alarm system in continuous processors are film break alarms. These alarms indicate when a break has occurred and locate the section of the processing machine where the break has taken place. Because of the speed in which the film is traveling in most continuous processors, it is imperative that immediate attention be given to repairing a break. A method used in one particular machine is predicated on the bottom bank of rollers dropping in a tank, due to a break and slack building up. Attached to the bottom bank of rollers is a long shaft that protrudes above the level of the tanks. Fastened to the top of the shaft is an arm that actuates a microswitch when the bottom rollers drop. The switch in turn actuates an alarm. Location of the trouble is based on either the varied sound of the alarm or a common sounding alarm used throughout the machine sections and a pilot light on a panel board indicates where the break is located.

Re-exposure Lamps

In most reversal processes, to obtain a reversal image, a second exposure or re-exposure is required. If the light intensity is decreased or there is a complete light failure, the photographic quality will be impaired. One method of overcoming this partial or complete light failure is by employing a photoelectric device. A photocell is located in or near the re-exposure housing. If the light intensity falls below a certain value, a second stand-by lamp is thrown on. Another method involves the use of a relay that is either energized or de-energized when the filament of the re-exposure lamp is burned out, causing a second lamp to be turned on. Both of these systems can be constructed so as to sound an alarm. Be-

cause of space requirements not permitting a second lamp to be located in the re-exposure lamp housing, the alarm system is quite often used, and the burned-out lamp is quickly replaced.

Darkroom Door Interlocks

On some occasions, films have been ruined or the quality seriously degraded due to light fog. An area where much of this fogging may have occurred, is in the film processing darkroom. To alleviate the possibility of light fogging in the darkroom, it is necessary to prevent any white light from entering the darkroom from the outside and prevent any white light from being turned on in the darkroom when customers' films are stripped or uncovered. There are many types of interlocks on darkroom doors and also mazes and special entrances to darkrooms that are quite satisfactory, however, a system that is quite inexpensive and requiring the least amount of space is an interlock blackout system. This system is similar to that used on ships during time of war. When a door is opened, a microswitch is released causing all the lights in the vicinity to black out. To assure against any malfunction of a switch, the use of two switches can be employed the switch located in such a position that, if it should fail, the lights in the vicinity would not go on.

Many darkrooms have white lights that are mounted in the ceiling or other places that are controlled by a switch located in an inconvenient place, or the switch must be operated with a special key or other variations of the same thing. It has been found that because of excessive moisture in the darkroom, the possibility exists that a defective switch may cause a white light to go on in a darkroom. It is strongly recommended that no white light be located in a photographic darkroom. After a processing run has been completed and light is required in a darkroom area for cleaning, maintenance, etc., that a light can be brought into the room with an extension cord. There are gadgets available to feed or retract electric wire on a spring-operated roller that can be mounted in the light room area to bring white light into the darkroom.

Conclusion

Color photographic materials are being improved constantly. This may be due to the fact that the users of color film and color print materials are becoming more sophisticated. Whatever the reason may be, the color-finisher will also have to improve his methods. One way of bringing about this improvement is to aid the processing machine operators with the use of alarm systems.

A 35MM COLOR SLIDE DUPLICATION BENCH

John O. Brostrup*

Thirty-five millimeter lantern slides are being used in ever-increasing quantities in advertising, in visual education, and in scientific and other fields. The growing demand for duplicate slides in quantity is being met in a variety of ways, depending upon the requirements in individual cases.

This paper describes a bench that meets the problems peculiar to one installation, but all or part of its design may be incorporated or altered to suit other requirements. The bench, which is semi-automatic, will accept originals from 35mm to 8" × 10" in size, and any portion of the original may be copied onto 100 foot rolls of 35mm color film. Originals are changed manually, but once framed, focused, metered, and the exposure time set, any number of duplicates can be made automatically.

The paper describes technical details of the bench and also considers masking, exposure standardization, and quality control of 35mm color duplicates.

SCIENTIFIC MEDICAL PHOTOGRAPHY at the Armed Forces Institute of Pathology had its start with the work of Joseph J. Woodward, Surgeon, Grand Army of the Republic, in 1863, and has a history of continuous progress. Throughout these 93 years, equipment, materials, and techniques have kept pace with improvements in photographic technology. When commercially produced equipment has not met specific requirements, custom-made apparatus has been designed and produced within the facilities of the Institute. The constant aim has been to have available the most advanced equipment, materials, and techniques, as tools for use in medical research. This paper illustrates how a specific problem is solved at the Photography Division, Armed Forces Institute of Pathology.

* Assistant Chief, Photography Division, Medical Illustration Service, Armed Forces Institute of Pathology, Washington, D. C. Presented at the National Convention of The Photographic Society of America, Boston, Massachusetts, 8 October, 1955. Received 22 June, 1956.

Equipment Required

In addition to the custom-made 35mm duplication bench, which will be described later, the following equipment is used:

1. *A densitometer.* This laboratory uses the Ansco MacBeth Model 12 Densitometer. The densitometer used should have an aperture suitable for reading very small areas. The Ansco MacBeth Model 12 densitometer has a custom-made aperture plate with a hole 1.25mm in diameter. The Kodak Color Densitometer Model 1 is satisfactory.

2. *A light standardizing meter.* The AFIP uses a Model 200M Photovolt Light Meter for standardizing exposure conditions of masks. The Model 200M Photovolt meter has a sensitivity of 2 foot-candles when the meter reads 100 on HIGH. The HIGH scale is 10 times the Low scale. Thus 10 on Low equals 100 on HIGH. All readings are taken with the base of the cell on the film plane or at the film plane plus glass.

3. *A precision timer.* The Model TM-8 Lectra-Laboratories Electronic Timer is used for making exposures with 1/10-second accuracy.

4. *Voltage control.* A Model V-1M Variac Voltage Regulator Transformer with voltmeter will serve this purpose. All exposing conditions are standardized at 120 volts with exposing lamp ON.

5. *An 8" × 10" contact printing frame.*

6. *An 8" × 10" piece of thinly flashed opal glass,* free from striations, bubbles, or specks.

7. *Several pieces of flawless water glass.*† Glass of this type gives the minimum color change to original transparencies and is of consistently high quality. The items listed in 2 to 6 are show in Figure 1.

When the enlarger is used as a light source only, as in making masks, it is racked up fairly high, and the lamp and lens are adjusted to give as even illumination as possible. To assure absolute uniformity of illumination a piece of thinly flashed opal glass is placed in front of the lens, and a cone of black paper is inserted between the lens and opal glass to prevent stray light from reaching the easel.

Preliminary Considerations

An original color transparency, at best, is only an approximation of the scene before the camera. A duplicate is only an approximation of the original transparency. Thus a duplicate is an approximation of an approximation. Yet the layman customer will criticize a duplicate made with utmost care, saying, "But it doesn't look like the original." Several people now have numbers assigned to them for failing in their efforts to make "duplicate" $10 bills; yet an item infinitely more complicated than a greenback is expected to attain ultimate resolution of detail and fidelity in all regions of the spectrum. This is not said in justification of some of the work that passes for good duplication of color lantern slides. Both requester and producer of color duplicates should have an appreciation and understanding of the complex problems involved in color duplication. These problems are thoroughly discussed by Evans, Hanson, and Brewer in "Principles of Color Photography," Chapter XV—Duplicating.

Only color transparencies of the best quality should be selected for duplication. If possible, deficient originals should be remade before duplication. Originals should be clean and free from artefacts and from the mold that often collects when they are bound between glass. Originals that are mounted in glass as slides should be removed from the mount, because binding glass is often greenish or of varying colors which would affect the color balance of duplicates.

Masking

The theoretical and practical problems of duplicating color transparencies are covered in the references at the end of this paper. To summarize, duplication without masking results in the following distortions, along with an increase in contrast.

"*Cyans:* darker and less saturated; → green (slightly).
Magentas: less saturated; → red (strongly).
Yellows: less saturated; → orange.
Reds: slightly lighter and less saturated; little change in hue.
Greens: darker and less saturated; → cyan.
Blues: darker and less saturated; → cyan."[1]

It is possible, by means of multiple masking, to produce duplicates that, to a high degree, satisfactorily approximate the originals. Depending upon considerations of economy and fidelity requirements, one or more masks may or may not be practical. When masking is required only a single principal mask that needs no special registering pin device is used, therefore none is incorporated on this bench. If multiple masking is anticipated, it would be relatively simple to install the required registration pin devices.‡ Where delicate highlights are of prime importance a highlight mask should precede the making of a principal mask.

Highlight Masks. The original transparencies at the Armed Forces Institute of Pathology rarely require highlight masks. When required they are made as follows:

The general density and contrast requirements of highlight and principal masks described in "Color Separation

† This glass may be obtained from J. G. Saltzman, Inc., 480 Lexington Avenue, New York, New York.

‡ Multiple masking registration pin equipment may be procured from the Condit Manufacturing Company, 37 Lakeview Terrace, Staten Island 5, New York.

Fig. 1. Model 200M Photovolt in use. Opal glass in front of lens and position of filters. Also shown are the timer and voltage control.

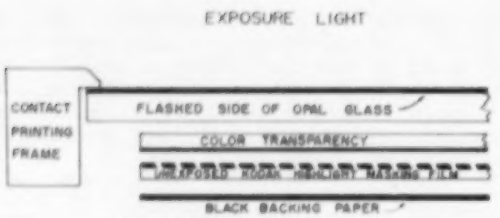

Fig. 2. Orientation of opal glass in printing frame, color transparency, Highlight Masking Film, and black backing paper during exposure of the highlight mask.

and Masking," Eastman Kodak Company,[2] apply to this system. The manner of producing these masks, however, has been somewhat altered.

For both highlight and principal masks the enlarger is used as a light source. In front of the lens is placed a piece of thinly flashed opal glass (Figure 1). Instead of a Kodapak Diffusion Sheet, a second piece of thinly flashed opal glass is used as a diffusion medium, BUT NOT IN THE SAME POSITION AS THE KODAPAK SHEET.

The orientation of opal glass, color transparency, Highlight Masking Film, and black backing paper during exposure of the highlight mask is shown in Figure 2. A backing sheet of matt-surfaced black paper minimizes the likelihood of halation when highlight and principal masks are made. The emulsion of the Highlight Masking Film is placed in contact with the emulsion of the color transparency and normally would be considered a sharp mask. The opal glass, however, has a diffusive influence that makes for ease of registration and eliminates "edge effect" in sharp-edged high contrast areas even with very great enlargements from 35mm originals.

Metering for highlight masks is standardized at 20 on HIGH on the Photovolt Model 200M Meter. Exposures may vary widely, depending on the density of the diffuse highlight area of the original color transparency. Experience indicates exposure times in the range of 3 to 15 seconds. Development is in Highlight Masking Film Developer for 4 minutes, with constant agitation, in a tray at 68 F. A small volume of fresh developer is used for each sheet of film.

All masks are fixed, washed, rinsed in Photo-Flo Solution, and dried at room temperature in the shortest possible safe time to minimize size changes and consequent poor registration. Since the masks need not last indefinitely they need not be washed for more than 10 minutes.

With 35mm originals the highlight mask is registered on the emulsion side of the color transparency; then the emulsion of the highlight mask is scratched with a needle run around the inside edge of 2 opposite sprocket holes. After the principal mask is made, the exposed lines where the scratches were made will facilitate the registration of the principal mask to the color transparency.

Principal Masks. Control of contrast is the main concern in a single mask system if there are no greens or blues. The greatest hue shift occurs in the greens and blue-greens. A single mask made on Pan Masking Film with a Wratten Filter No. 33 will lighten the greens. If lighter blues are also desired, a Wratten Filter No. 29 is recommended. Since most originals at the Armed Forces Institute of Pathology are medical subjects, predominantly reds and yellows, masks are usually made without filter.

Orientation of opal glass, highlight mask, color transparency, Kodak Pan Masking Film, and black backing paper during exposure of the principal mask is shown in Figure 4.

Metering for principal mask exposure is standardized at 20 on HIGH, WITHOUT FILTER. Exposure will vary between 8 and 40 seconds for a mask from the #29 filter. Development is in DK-50 diluted 1 to 4, in tray at 68 F for 4 minutes. The mask is then rinsed, fixed, washed for 10 minutes, and rinsed in Photo-Flo Solution before drying. The principal mask is registered on the base side of the original color transparency.

The usual practice at the Armed Forces Institute of Pathology is to mask all color transparencies of gross specimens, comparable to all general scenes, portraits, etc., but NOT to mask photomicrographs. Photomicrographic color transparencies of stained sections are usually of low to moderate contrast. The increase in contrast resulting from duplication of unmasked photomicrographic transparencies is usually an advantage. In a limited number of original photomicrographic color transparencies where special staining and the physical characteristics of cell nuclei result in high contrast, a contrast control mask is applied.

Masking is usually to the extent of reducing the original density range to about 1.30; thus, if the original transparency has a high density of 1.90 and a low density of 0.30 a mask is made which when registered with the original will result in densities of 1.94 and 0.64. To accomplish this the mask will have densities of 0.04 (base density) and 0.34. The practice at the Armed Forces Institute of Pathology is NOT to generalize on a principal mask of 25 to 33-$^1/_3$ per cent of the original color transparency but to make one that will reduce the contrast range of the original to about 1.20 to 1.30. This results in greater uniformity of contrast of duplicates.

Standardization of Exposure in Duplication

Duplication of color transparencies in volume necessitates standardization of exposure to assure high productivity and minimum wastage. It would be desirable to keep exposure time constant and vary the light level either by f/stop or increased or decreased illumination. Keeping exposure time constant would minimize consideration of color shifts due to failure of the law of reciprocity. It has been impractical to approach the exposure problem on the basis of a common duration

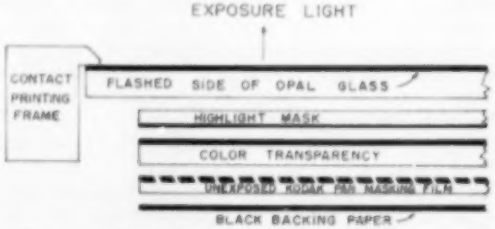

Fig. 3. Orientation of opal glass, highlight mask, color transparency, Pan Masking Film, and black backing paper during exposure of the principal mask.

for all transparencies, because of the wide range of densities of originals that are duplicated at the Armed Forces Institute of Pathology and the inability to vary light levels over a wide range while keeping color temperature constant.

The policy at the Armed Forces Institute of Pathology is to work with a fairly high level of illumination, keeping exposure times in the range of 0.4 to 4 seconds. Since there is a wide variation in original color transparency sizes, changes in bellows extension are acommodated by changing the f/stop.

An arbitrary scale of duplication exposures has been determined, based upon a predetermined level of illumination at the unexposed film plane and exposures calculated on densitometer readings of the thinnest useful highlight of the original transparency. In the case of masked originals the reading is taken with mask registered on the transparency.

Original color transparencies are calibrated on a densitometer having a scale of duplication exposures vs. highlight densities as shown (Figure 5):

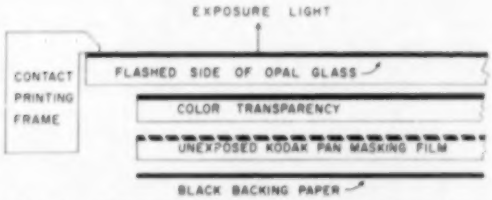

Fig. 4. Orientation of opal glass, color transparency, Pan Masking Film, and black backing paper during exposure of the principal mask when no highlight mask is involved.

These exposures are for color transparencies of average contrast with a density range of approximately 1.5. The ideal original color transparency will have a highlight density of approximately 0.4 and a shadow density of approximately 1.9. Color transparencies of high or low contrast will not have duplicating exposure times as in Figure 5. Those of Low contrast will have exposures SHORTER than the highlight density exposure indicates. Those of HIGH contrast will have exposures LONGER than the highlight density indicates. Color transparencies having a color or contrast control mask attached will fall into the soft contrast category; thus, they will require a shorter exposure than the scale indicates. Experience and judgment in evaluating color transparency contrast will enable the calibrator to arrive at exposure times that almost invariably will be correct.

At the Armed Forces Institute of Pathology the operator who does the calibrating also inspects the finished duplicates. Thus he develops judgment in determining the extent and direction of deviations from the density-exposure scale. Original color transparency calibrations average over a hundred a day and remakes due to exposure error are rare.

Color Compensation Filtration

The Armed Forces Institute of Pathology makes large numbers of color duplicates on both sheet film and 35mm roll film. Experience has shown that for a set of parallel conditions, different originals require different color-

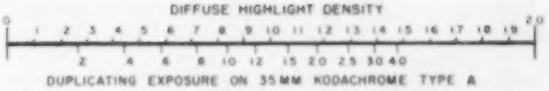
DIFFUSE HIGHLIGHT DENSITY
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
2 4 6 8 10 12 15 20 25 30 40
DUPLICATING EXPOSURE ON 35MM KODACHROME TYPE A

Fig. 5. Density-exposure scale for duplicating on 35mm Kodachrome Type A.

compensating filters for optimum VISUAL evaluation. That is, assuming (1) that all originals are on one Ektachrome emulsion that were developed in 1 batch, (2) that duplicating lamp voltage is carefully stabilized, (3) that all duplication exposures are on the same emulsion and of the same duration, and (4) that all duplicates are developed in a single batch, different originals will require different color-compensation filters.

This is a problem of great concern because of the critical fidelity requirements of medical photography and the fact that in the field of pathology, photography is often a great factor in diagnostic evaluation. Some work has been done and is continuing toward a scientific method of predetermining correct color compensation filter combinations for different original transparencies. Until a method is worked out, the selection of filters remains a matter of experience, judgment, and care in keeping controllable conditions uniform.

When 100-ft rolls of 35mm color films are used in a magazine, it is not practical to vary the CC filtration for different original transparencies. The practice at the Armed Forces Institute of Pathology is to give the best average CC filtration to this type of volume duplication. All $3^1/_4'' \times 4''$ slides and the larger sheet film sizes of duplicates are given individual masking (occasionally multiple masking) and individual CC filtration.

A group of 20 original color transparencies of widely differing subject matter and original film material is retained as a master reference set. When a new emulsion is received, the reference set of originals is exposed with several different CC filters and processed. The result of this test determines the selection of CC filtration for duplicating on that particular emulsion. The Armed Forces Institute of Pathology duplicates primarily on 35mm Kodachrome Type A. Rush duplicates are made on 35mm Ektachrome Type F developed in 100-ft Nikor reels. With the light source described later the following CC filtration is generally used: for Kodachrome Type A, 15B for photomicrographs and 15M for gross subjects (general scenes); for Ektachrome Type F, 10C for photomicrographs and 10C plus 10G for gross subjects.

The 35mm Lantern Slide Duplication Bench

The standard equipment in use at the Armed Forces Institute of Pathology was not adequate to meet the increasing demand for 35mm duplicates. The general requirements to be met by a 35mm duplication bench were determined and plans for its construction satisfied the following conditions:

1. A full double-frame 35mm duplicate of originals from $^2/_4$ of the area of a 35mm slide to all of an $8'' \times 10''$ transparency.
2. Standardization of exposure conditions.
3. Automatic exposure and film advance, once framing and exposure standardization has been set.
4. Electrical circuitry designed to assure a relatively foolproof system.

The following component parts and assemblies were obtained before construction was started:

1. A Model TM-8 Lektra-Laboratories Electronic Timer for making exposures of $^1/_{10}$ second accuracy in addition to the one used for masking.

2. A Model 200M Photovolt Light Meter for standardizing exposure conditions for duplication in addition to the one used for masking.

3. A National Cine Equipment, Inc., Model AMC-115 Volt motor, solenoid, clutch and gear driving mechanism for advancing individual units of double frame 35mm film.

4. An Agastat Type NE-12, 115-volt time-delay relay. This time-delay relay requires no recuperation time between cycles.

5. A standard set of 35mm sprockets and gate. The film advancing sprocket moves $^1/_4$ turn per each double 35mm frame.

6. A Leica bellows attachment.

7. A shutter. Practically any shutter of approximately 1″ diameter opening will suffice. The shutter on this bench is a Kodak Supermatic with the gear train removed because the only operating condition is BULB.

8. A 4″ Goerz Apochromat Artar lens. This lens is mounted in the Supermatic shutter.

9. Several 35mm 100ft roll magazines. More than one is needed if, as at the Armed Forces Institute of Pathology, black-and-white and color 35mm lantern slides are made.

10. The lens board, gear drives, and track from a process copy camera. In this set-up a war surplus Robertson process camera was used. The reversible motor drive of this camera, for raising and lowering the halftone screen, was adapted to drive the light box.

Construction of the bench was done entirely in the shops of the Armed Forces Institute of Pathology. It is hoped that the illustrations are sufficiently detailed to make the features of the design clear. Dimensional measurements have not been stressed, for each bench made would fulfill individual requirements.

Figure 6 shows the bench. The track is suspended on vibration absorbent springs to assure damping of any building disturbance. All modern process cameras have spring suspension and this is vital to preservation of fine detail resolution of small cells in photomicrography. The centering and alignment controls of the original transparency are located below the control panel. The left knob controls the clockwise or counter-clockwise movement. When the right control is PUSHED IN and turned right or left it raises or lowers the original transparency. When this same control is PULLED OUT and turned right or left it moves the transparency to the left or right. An inch/millimeter steel tape is located just to the right of the right hand control for ease in repositioning the lamphouse carriage to previously determined positions.

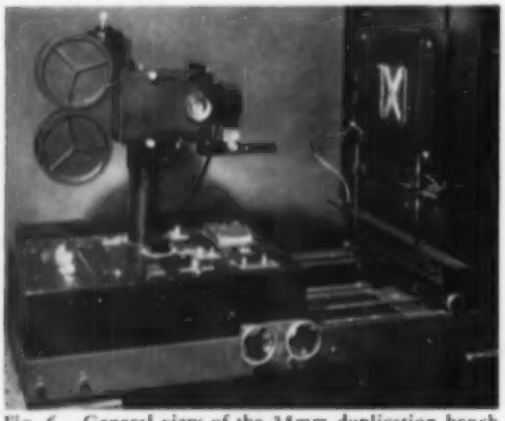

Fig. 6. General view of the 35mm duplication bench from the operating side.

Fig. 7. Detail view showing how either cardboard or glass-bound 35mm lantern slide originals can be mounted on a single aperture plate.

The lamphouse is adequately ventilated by a darkroom blower that is independently shock mounted. The current of air is directed across the carrier for original transparencies. Four R-2 Reflector Floods are used. The lamphouse has an opening cut in the side covered by a deep filter with a mirror set to reflect the image of the lamps back to the operator. This permits the operator to have a constant check that all lamps are burning. In the center of the 4 sockets is a receptacle for the 500-watt focusing lamp.

The method of mounting original transparencies is shown in Figure 6. Separate aperture plates carry the 35mm, $3^1/_4'' \times 4''$, $4'' \times 5''$, $5'' \times 7''$, and $8'' \times 10''$ originals (see Figures 6 and 7). All except the 35mm plates have a sliding clip that secures the original transparency sandwiched between 2 pieces of water-clear glass (see Equipment Required). The 2 sheets of glass are held together along 1 long edge by a strip of Scotch tape to make a book type holder for original transparency films. The lateral, vertical, and rotational gear mechanisms can also be seen in Figure 6. These gears have sufficient travel to permit 35mm duplication of a $4'' \times 5''$ area from any part of an $8'' \times 10''$ transparency, as well as the complete $8'' \times 10''$ area.

An opaque copy board could be mounted very easily on the aperture plate so that the lateral, vertical, and rotational movements would still be retained when copying opaque copy down to 35mm. Two copy lamps on gooseneck receptacles could be mounted on the lamphouse face plate so that they would ride along with

it when the motor changed the camera-subject distance. With the 4″ Artar lens, the limits of original to 35mm copying are from 30 per cent enlargement to full coverage of 8″ × 10″.

Figure 8 shows the camera unit with Leica bellows extension, shutter solenoid, and 4″ Artar lens. A spacer block is placed between the lens frame and the focusing bed. A positioning lever at the top of the camera controls the reflex mirror, light cell, safety shutter, and exposure shutter solenoid switch. The reflex view finder is also shown. The 4″ Artar lens on the Leica bellows extension allows 35mm duplicates to be made from 75 per cent of the area of a 35mm frame to the entire area of an 8″ × 10″ transparency.

The threading of the camera is shown in Figure 9. The safety microswitch indicating film supply can be seen at the bottom. When films runs out, the microswitch illuminates the red panel and the entire camera circuit is rendered inoperative.

The elements of the camera body from the rear may be seen in Figure 10. The camera body was constructed of 1/4″ semihardened aluminum. The drive shaft of the film advance gear box engages in the reduction gear sprocket in the right section of the camera. To the left may be seen the back of the mirror, light meter cell, and safety shutter, and on top their positioning lever.

Fig. 8. Detail view of the camera unit showing the solenoid for actuating the shutter.

The positions of these elements are shown in the 3 illustrations comprising Figure 11. Figure 11a shows the arrangement when focusing and framing on the ground glass. Figure 11b shows the arrangement when metering. The light cell has moved into the optical axis, and the mirror closed against the ground glass to make a light seal. Figure 11c shows the arrangement during exposure of the duplicates. The mirror and meter cell are out of the axis, the safety shutter is open and the lens shutter is closed.

The control panel is shown in Figure 12. On the left is the TM-8 Timer with its own power switch and green lamp indicating that it is ready for operation. The time of exposure is determined by the total of the 3 dials; thus the time is now set for 1.5 seconds. The main power switch has a 2-way throw, 1 for focusing and the other for exposing.

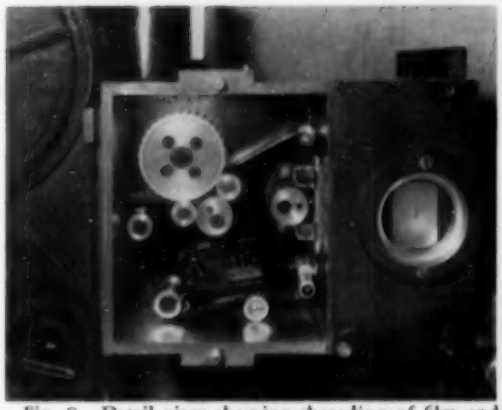

Fig. 9. Detail view showing threading of film and film advance mechanism.

At the upper right corner is the Model 200M Photovolt Meter, which is activated when the light cell is brought into the optical axis by the positioning lever. At the lower right are 2 microswitch buttons for activating the forward or reverse motion of the lamphouse carriage. A protective shield prevents inadvertent depression of the buttons. The motor and gear train for movement of the lamphouse is extremely sensitive, with a selectivity of movement of the carriage of 0.25-mm in either direction.

At the top right center of the panel is a manual wind button for advancing film to leave a blank space between duplication jobs. At the top left center of the panel is the red film supply lamp.

In the center of the panel is the reset accumulator dial. This dial is set for the number of duplicates desired from 1 transparency. The reset accumulator assembly was fabricated in its entirety by the Armed Forces Institute of Pathology machinist. It consists of a 115-volt AC solenoid, which advances a ratchet 1 notch for each exposure. On top of the rachet is the dial with numbers corresponding to the teeth of the ratchet. Affixed to the dial on the underside is a finger that opens a microswitch when it reaches zero, thus ending further exposures.

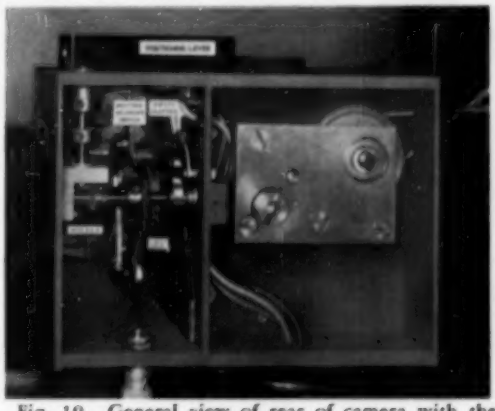

Fig. 10. General view of rear of camera with the film advance motor and gear box removed.

A spring-loaded pall limits movement of the ratchet to 1 tooth per each stroke of the solenoid. The sequence-start button and light and the single-exposure button and switch complete the control panel. The operation of this panel will be explained later.

Electrical Circuit

Figure 13 shows the underside of the control panel. The TM-8 Timer was modified in that the main power relay is not used. Instead, the timer is used to actuate the power relay R-1. When R-1 is activated it holds the film advance motor clutch trigger solenoid R-5, $^1/_4$ second. After the film advance has stopped, R-2 is activated $^1/_4$ second to allow the film to come to rest before R-4 is activated. R-4 activates the remote timer circuit, starting the next exposure. The 1-second delay of the Agastat relay is to allow for film advance after the shutter has closed. R-3 is held closed by the accumulator cut-off switch, which holds it until the desired number of exposures are made. The accumulator circuit is initially activated manually by the sequence start switch. The shutter solenoid operates on 110-volt DC to eliminate vibration. No special voltage stabilizer or regulator is incorporated in this circuit, since there are special constant voltage circuits throughout the Armed Forces Institute of Pathology, Photography Division.

Operation of the Bench

As described earlier, the original color transparencies come to the bench with duplication exposures calibrated on each. The original is mounted in its appropriate aperture plate. The timer is set for the calculated time. The positioning lever is moved to focus and the framing done on the ground glass. The original is then

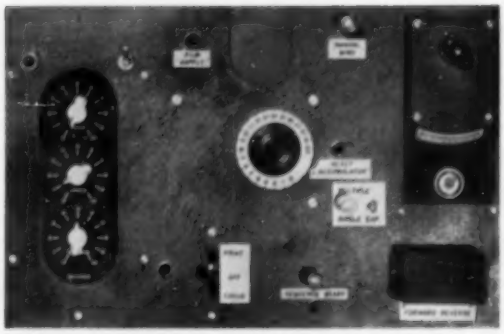

Fig. 12. Detail view of the control panel. The main power switch has a two-way throw, for focusing or for exposing.

removed for the purpose of standardizing the level of illumination.

The positioning lever is next set to meter position. On the basis of the trial filtration of the tests for a given emulsion the proper CC filters are incorporated into the optical system. Experience has proved that more than one CC filter, either in front of or behind a lens, will cause serious loss of resolution and contrast because of the reflection of light from and between the surfaces of CC filters. Gelatin filters are used exclusively at the Armed Forces Institute of Pathology. The number of CC filters is kept to an absolute minimum, preferably only one mounted in front of the lens. If more than one CC filter is required, they are placed immediately behind the transparency aperture plate on the duplication bench.

It cannot be emphasized too strongly that use of more than one CC filter on either side of the lens will cause

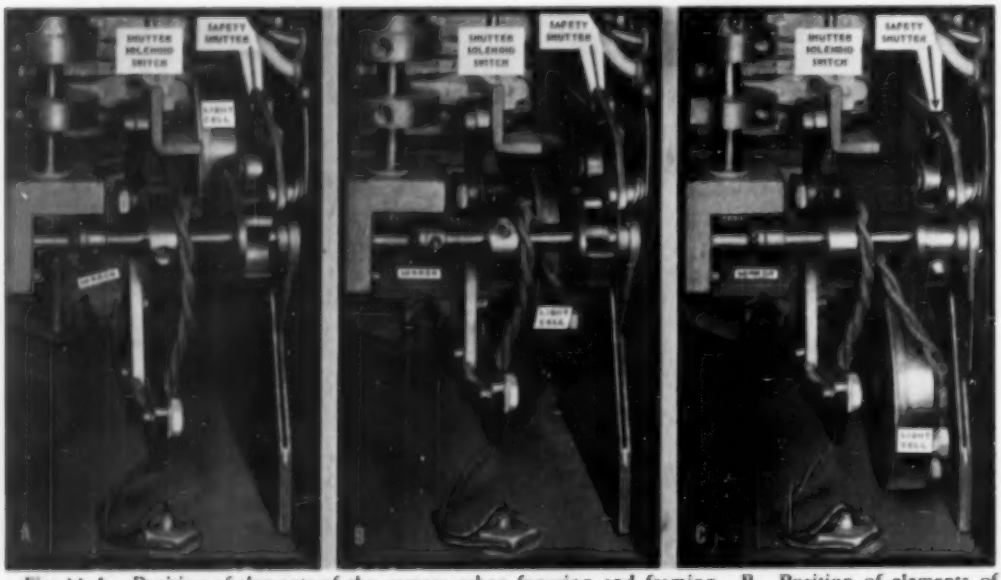

Fig. 11-A. Position of elements of the camera when focusing and framing. B. Position of elements of the camera when metering. C. Position of elements of the camera when exposing.

serious losses. On small cell photomicrographs this is readily apparent. When duplicating by means of an enlarger, such as the Omega D-II with a color head, one CC filter can be used on each side of the lens. Any additional filters must be placed in the color head. Because of heat deterioration of CC filters, 3 × 3 gelatin filters are used at the lens where possible. These filters must be clean and free from abrasions and fingerprints.

On the duplication bench it is impossible to insert a filter behind the lens. When more than one filter is required they are placed behind the original transparency. Complete series of CC filters in all densities, sizes 3″ × 3″, 7″ × 7″ and 8″ × 10″, are on hand to accomplish the solution of filtration problems involving various exposure conditions, materials and original transparencies.

The original is replaced in the aperture plate and checked on the ground glass for framing only. The positioning lever is moved to exposure. The bench is now set to make any number of duplicates desired from this original. The dial may be set to any number from 1 to 20. The sequence start button is pressed and the electrical circuit takes over, making an exposure, advancing the film, making an exposure, advancing the film, etc., until the accumulator dial reaches zero, which automatically stops further exposures.

If only one duplicate each is desired, the dial is not used. Instead, the single exposure circuit switch is turned on, the dial advanced to any number other than zero, and the sequence start button depressed once (see Figure 12). The circuit will now give only one exposure, for each depression of the single exposure button. When less than 5 duplicates each are made it is the practice to use the single exposure circuit. After the desired number of duplicates have been made the original transparency is replaced by another. If there is no change in bellows extension, the only preparation is to set the timer for the new exposure time and to frame. If originals are grouped according to original transparency size, very little metering will be required. The only purpose of metering is to accommodate for differences of f/value due to bellows extension.

At the Armed Forces Institute of Pathology duplicates usually are made in lots of 5, 10, 15 or 20 each, or sometimes 50. When 10 each are made with relatively little change in bellows extension and consequent metering, a full 100-ft roll, or 800 duplicates can be exposed in 2½ hours.

The exposed film is processed and returned on a spool. This imposes a problem. The machine is producing duplicates far faster than they can be bound at the present time. The Armed Forces Institute of Pathology engineering and machine shop is now working on a semi-automatic binder and the objective is to bind at least one slide each 5 seconds.

Supplemental Notes

Black-and-white 35mm lantern slides are also made on this bench using Kodak Positive Release stock No. 5302. The techniques of copying radiographs onto 35mm Kodachrome are covered in references 3 and 4. Large runs of 35mm copies of radiographs have been made on this bench using these techniques.

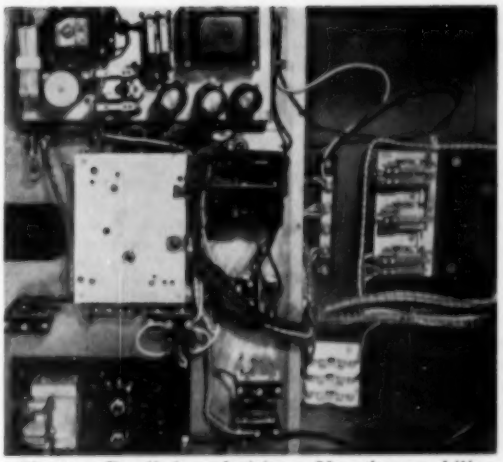

Fig. 13. Detail view of wiring. No voltage stabilizer is needed since special constant voltage supply circuits are available.

On the whole the 35mm duplication bench described herein has proved to be very satisfactory. The only difficulty has been failure of the motor clutch safety shear spring on 2 occasions because of improper threading.

After completion of a binding machine, a 70mm head for this same bench is contemplated. The wiring to the camera unit has quick disconnects to facilitate changes. Film 70 mm wide × 100 ft would be used for 3¼″ × 4″ lantern slides, which are still made in considerable volume.

Acknowledgments

The general concept and function of this machine were planned and initiated by Mr. Julius Halsman, Chief, Photography Division, Armed Forces Institute of Pathology. Optical specifications and other advisory consultation were contributed by John O. Brostrup, Assistant Chief. Design and mechanical engineering and machining were done by SFC Oliver Hutson, machinist for the Medical Illustration Service, Armed Forces Institute of Pathology. Electrical circuitry by SFC Oliver Hutson and Sgt. John Waddell.

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IMPORTANT CHARACTERISTICS OF COLOR PHOTOGRAPHIC MATERIALS

W. Lyle Brewer*

ABSTRACT

Important characteristics of color photographic materials may be considered in terms of tone scale characteristics, color characteristics, definition, physical characteristics, and uniformity of product. Each of these characteristics is discussed as it applies to reversal films, negative films, prints from reversal films, and prints from negative films.

Successful operation of a color photofinishing business implies satisfied dealers and satisfied customers of the dealers. The dealer's direct interest in the operation is largely a financial one. His customer, who is the ultimate consumer in the photographic enterprise system, has multiple interests. He wants his color photograph to be as inexpensive as possible. He wants convenient service, and he wants it to be as fast as possible. He also wants a color picture that will be pleasing.

Customer satisfaction with the color photograph as a photograph is influenced by many factors. Working to the advantage of the photofinisher in increasing this satisfaction is generally the fact that the photograph represents something of immediate and direct interest to the customer: a member of the family, a friend, or a cherished scene. This same interest and familiarity with the subject may, of course, also enable the customer to be much more critical of the photographic result than the photofinisher can be because the photofinisher has no opportunity for such acquaintance with the subject. Regardless of the pictorial content, however, the customer is apt to decide that there are features he does not like about the photograph. These reactions may considerably influence the number of color photographs he purchases and also his choice of photographic materials.

The characteristics of a color photographic material that are likely to be of importance to the customer probably could be analyzed in a number of different ways. For purposes of the present discussion, they may be considered in terms of five major aspects: tone scale characteristics, color characteristics, definition, physical characteristics, and uniformity of product.

Color Print Characteristics

By "tone scale characteristics" is meant the brightness reproduction aspects of the photograph, particularly as it applies to the reproduction of neutral colors. "Color characteristics" refers to stain, neutral colors as they are reproduced in the photograph, color appearances of particularly important colors, and color appearances of saturated colors. "Definition" pertains to picture sharpness, graininess, and resolution. For want of a better term "physical characteristics" is used to apply to scratches, digs, dirt, and similar factors. "Uniformity of product" relates to the extent that the pictures in any pair which should look alike do, in fact, look alike.

Some of these characteristics can be controlled to a large extent by the photofinisher. Others he can control to some extent. Over some he has little or no control. Regardless of the extent of his control, however, they are characteristics that influence customer acceptance of color photographs. For this reason the photofinisher should be aware of them and be able to recognize them in photographs he examines. To the extent that he can control them, he should do so to obtain the best possible product. Those characteristics that he cannot control are of importance in his relationships with the manufacturer of photographic materials, and in his decisions as to what particular products he may wish to handle.

The four major types of product concerned with in commercial color photofinishing are: (1) reversal films, (2) negative films, (3) prints from reversal films, and (4) prints from negative films. Reversal films and the prints made from them are end products that in themselves are of value to the customer. Negative films are of value only in terms of the prints that can be made from them. Because of the differences in the natures of the products, and the purposes served, each of these types of color photographic materials presents its own special problems. For this reason, it is often necessary to consider each separately in dealing with the various characteristics.

Tone Scale Characteristics

Two aspects of tone scale are particularly important in color photography. One is contrast and the other is tone scale range. Tone scale range pertains to the total range of density in the photographic material or, its equivalent, the total range of luminance in the light from the photographic material. Transparency materials designed for viewing usually have a tone range in density of about 3.0. This corresponds to a relative luminance range of 1,000 to 1. Reflection materials generally have effective density ranges no greater than about 1.7 to 2.0, corresponding to luminance ranges of about 50 and 100 to 1. This difference in tone range between transparency and reflection print materials provides one reason why it is not generally possible to match a reversal print to the transparency from which it is derived. If the transparency has a long tone scale, some of it must necessarily be lost in making a

* Color Technology Division, Eastman Kodak Company, Rochester 4, New York. Presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York, 25 May 1956. Received 9 July, 1956.

print from it. This means that the lighter areas tend to be washed out, the darker areas tend to be blocked up, or possibly both.

Contrast pertains to the manner in which brightness differences in the original scene are reproduced in the photograph. In a material of high contrast, these differences are exaggerated. The result is usually that of a harshness or hardness of appearance. Transparency duplicates generally have higher contrasts than the originals from which they are made and, for this reason, are seldom as pleasing as the originals. Furthermore, as the tone scale range is usually no greater in the duplicate than in the original, detail at the two ends of the tone scale is usually lost.

One advantage of high contrast in a photographic material is that, with the dyes used in photographic systems, it makes possible higher color saturations in the picture. For this reason contrasts are usually higher than they would be to reproduce exactly the brightness differences in the original scene. In designing a photographic material, the desirability of this feature must be balanced against the undesirable one of over-exaggerating brightness differences.

Color Characteristics

In considering color characteristics, the subject of stain deserves some attention. Stain in a color photograph refers to some kind of an unwanted dye remaining in the color photograph and giving it an over-all color cast. It is generally most noticeable in areas that otherwise would be completely transparent or white. Much more stain can be tolerated in a transparency to be projected than in a print material. The projection usually takes place in a darkened room and eye adaptation effects tend to cancel out the appearance of the stain. Prints, however, are usually viewed in a lighted room in which the eye adaptation is controlled by illumination and objects in the field of view other than the print. Stain in a print is often particularly noticeable in the border. Stain will often also be evident in any white or highlight areas.

A second color characteristic of particular importance pertains to the reproduced colors of objects that were neutral, or gray, in the original scene. The color balance of the photograph is apt to be judged largely by the reproduction of such colors. The general objective is to make them as nearly neutral as possible.

Consider a photograph taken out of doors. Daylight has relatively more blue light and less red light in it than has tungsten light. If tungsten-balanced film is used to photograph an outdoor scene that is illuminated by daylight, the color balance will be decidedly blue. In this instance the off-color balance results from the use of the wrong type of film. Similar results, usually not so extreme, may also come about because of improperly balanced emulsions, improper processing, or the taking of pictures outdoors in the early morning or late afternoon. Peculiar, though not necessarily unattractive, color effects are sometimes obtained in photographing a scene illuminated partially by daylight and partially by tungsten light.

A negative film is not intended for viewing and it is therefore possible to use a single type of film for both daylight and tungsten light. Color timing is then employed in the printer to compensate for lighting differences. One of the simplest ways of accomplishing color timing is by means of three-light printers in which the red, green, and blue light exposures are made in sequence. The time or intensity of each exposure is adjusted to obtain the desired result.

Color timing is generally not considered necessary in making reversal prints. It is for this reason that reversal printers are usually white-light printers. The reversal print is made from a slide that itself, presumably, is of satisfactory color balance. If the print is to match the slide in color balance, color timing is not necessary. Density timing is, of course, necessary, partly for the reason that the print cannot encompass the complete tone range of the slide.

Color balance problems may arise, however, in reversal printing. By way of example, consider a snow scene. In the shadowed regions the snow may be illuminated by blue skylight and therefore will have a bluish cast. If such a picture is taken on either a negative or reversal transparency material, this bluish cast effect will be recorded. Because of eye adaptation, the projected picture of the transparency will appear quite satisfactory. Also, a print from the negative will appear reasonable because color timing in the printing stage gives a print in which the snow is more nearly white. On a print made from the reversal transparency without color timing, however, the blue cast would be faithfully recorded, and would probably be quite objectionable. For such types of pictures in reversal printing it may be necessary for the printer operator to change the printer-light color balance.

Personal judgments with respect to the color quality of a photograph are also markedly influenced by its reproduction of particular colors. The color of flesh in a photograph is probably the one color to which people are most sensitive. Green grass and blue sky are also colors in which departures from correct reproduction will be quickly noticed.

Saturated colors give another indication of the color characteristics of a color photographic process. Different photographic processes differ in the extent to which they will give highly saturated colors. Also, the hues of such colors in the photograph will not always correspond well with those of the original scene. High brightnesses in saturated colors are not always achievable. In this respect, reflection prints are almost always inferior. Saturated colors cannot be made to come out as bright and striking as they do in transparencies.

Definition

Definition pertains to the clarity by which detail is reproduced in a photographic image. Its three main aspects are graininess, sharpness, and resolution. Light incident upon a photographic emulsion is absorbed by silver halide grains. Effective exposure of each grain is an all-or-none matter. The grain absorbs enough light so that, with the proper development, all of it may be reduced to silver, or absorbs insufficient light to render any part of the grain developable. Black-and-white photographic images are opaque where these grains develop, and transparent where they do not

develop. In subtractive color photographic images, small globules of dye form in the vicinity of each developed silver grain. The silver is later removed by bleaching and fixing, leaving the dye globules to form the photographic image.

Because it consists of discrete particles, it is evident that, if enlarged sufficiently, any color photograph must reveal its granular nature. Upon enlargement, however, long before the individual grains can be resolved, this granular appearance becomes evident.

Graininess places an upper limit on the extent to which photographs can be enlarged. It is likely to be more pronounced in high speed photographic materials than in those of lower speed. If a negative has high graininess, the appearance of graininess will be evident in the print made from the negative, even though the print material itself is fine-grained and, in itself, not prone to graininess.

The definition in a photographic reproduction is also dependent upon the sharpness of the images, that is, upon the appearance of the edges of well-resolved detail. Objects in a scene usually have distinct surfaces which should give sharp boundaries in the photograph. Because of light diffusion during exposure, and for other reasons, these boundaries in the photograph may not be sharp. The edge gradient will become evident upon enlargement in any photograph. As normally viewed, some photographic materials will be characterized by greater sharpness than will others.

A third aspect of definition of importance in color photographic materials is that of resolving power which is the ability of the material to record fine detail distinguishably. Resolving power is measured by photographing a suitable pattern on a reduced scale and then examining the image at whatever magnification is required to see the smallest detail that is resolved.

Physical Characteristics

The term physical characteristics is used here to apply to several miscellaneous factors affecting photographic quality that arise in the physical handling of photographic materials.

Dirt, digs, and scratches are among the most important of the physical characteristics. Dirt, particularly in the form of dust in the air, is an eternal problem in photofinishing. Wet emulsions must be especially protected because dirt particles lodged in such an emulsion are not easily removed either immediately or after the emulsion dries. Special care is also necessary in making prints either from negative or positive transparencies. Dust particles on the transparency can seriously affect the appearance of the print.

Emulsion digs can result from any rough handling of photographic materials, particularly when they are wet. Special care is necessary to prevent adjacent pieces of processed film from curling and contacting each other while drying.

Particular care is also required if scratches are to be minimized and, even then, it is nearly impossible to eliminate them completely. Practically all negative films sent in for reprints will show scratches. They occur, apparently, through the normal handling of the negatives by the customer and through the rubbing of the negatives against each other.

In transparency slides, the cutting and mounting equipment is a potential source of scratches. If the film rides along through a channel in the cutter, for example, there is always danger that tiny irregularities in the channel surfaces will cause scratches. This is particularly true if the film has excessive curl. Curl, in turn, depends upon drying conditions and subsequent humidity conditions up until the time the transparency is mounted. Thus, humidity and other drying conditions may influence film scratching.

As scratches cannot be completely avoided, the question arises as to whether anything can be done about them. For scratched negatives, much of the harmful appearing effects can be eliminated through the use of diffused light rather than specular light in the printer. Diffusion also is of some help for minimizing dirt and small digs.

In printing reversal materials from positive transparencies, diffusion may also help, but not to the same extent. Scratches here apparently do not give such bad visual effects, and, therefore, diffusion is not so important.

Uniformity of Product

Uniformity of product implies that the same quality of product is obtained consistently hour after hour and day after day. Ideally, repeat photographs on the same kind of photographic material should look exactly alike regardless of when they were processed or, for prints, printed and processed. In practice, such results are not obtained. Different emulsions will give slightly differing photographic results. Different photofinishing establishments are likely to obtain different results. Even within a given establishment, results are apt to vary as a function of time.

In reversal transparencies there is little that the photofinisher can do about emulsion-to-emulsion variations. The manufacturer, however, keeps these variations as small as possible. The photofinisher should keep his process close to standard. Equally or even more important, he should keep his processing conditions as much the same at all times as he can. Process constancy is an essential element of process control and provides the basis for a uniform product of high quality.

Emulsion-to-emulsion variations in print materials can be expected to be greater than for film. Fortunately, these variations can be largely corrected for in printing. Effective correction is possible, however, only if the processing variability is kept small. If the process is not steady, then printing conditions are apt to require frequent alterations. Such alterations necessarily will result in higher waste, lower average quality, and reduced efficiency of operation.

Summary and Conclusions

In dealing with important characteristics of color photographic materials, tone scale characteristics, color characteristics, definition, physical characteristics, and uniformity of product have been discussed. Each of these characteristics is one with which the photofinisher must be familiar and which he must take into account in ascertaining whether or not he is producing a satisfactory product.

Satisfactory quality in those characteristics that are under the control of the photofinisher will not necessarily come easily. Probably the first requirement for the photofinisher is a healthy respect for the manufacturer's instructions and recommendations. This would apply to all aspects of processing: processing times, processing solution temperatures, chemical mixing directions, drying conditions, control procedures, and solution replenishment and discard procedures. Mere acquaintance with the instructions and recommendations is not enough. Systematic checks must be established throughout the process to make certain that good intentions are not being defeated by oversight or carelessness.

Beyond this, the photofinisher's staff must gain experience in color photofinishing operations. Such experience, if developed through a careful following of instructions and recommendations, and through an understanding of the important characteristics of color photographic materials, should ultimately make it possible for the color photofinisher to operate effectively and highly successfully.

MATERIALS OF CONSTRUCTION FOR COLOR PROCESSING EQUIPMENT

John R. Turner*

ABSTRACT

Factors affecting the choice of materials for photographic processing equipment are discussed with particular reference to the requirements of color photographic processes. The effects of photographic solutions on the materials, and the effects of the materials on the film or paper being processed are considered. Specific examples of the type of difficulties that can be encountered are cited to illustrate these effects. The advantageous properties of some of the plastics are described.

THE DESIGNER of photographic processing equipment must give careful consideration to the materials to be used in its construction. The choice of materials will determine in large measure the ultimate suitability and durability of the equipment.

During photographic processing the chemical solutions must come in contact with materials that contain and carry these solutions, as well as those materials used to hold or to convey the photographic film or prints being processed. The interaction of the processing solutions and the materials used for construction must be considered from two aspects:

(1) The photographic properties of the solution may be affected by contact with the material, and
(2) The useful life of the material may be reduced by the solution it contacts.

The materials of construction of photographic processing equipment have been discussed very broadly and in considerable detail in the literature. Muehler and Crabtree have published a comprehensive work on this subject in the Journal of this Society.[1] Subsequently, the American Standards Association has issued a standard, specifying "Methods and Criteria for Determining the Chemical Resistivity and Photographic Inertness of Constructional Materials for Processing Equipment".[2] A paper on the testing of plastics was recently presented to the Society of Motion Picture and Television Engineers by Mr. B. A. Hutchins.[3] In these, emphasis is placed first on laboratory tests of the essential characteristics of the materials, and then, most importantly, application tests to determine how the material will function under the more complex conditions of actual use.

Many of the constructional materials used in the past are no longer considered to be advantageous. For instance, concrete or stone are less frequently used for tanks because many excellent newer materials are much lighter, are more easily cleaned, and are less bulky. In addition, the considerable sensitivity of color processes to solution contamination, and the highly corrosive action of the bleach solutions used in some color processes have imposed relatively severe restrictions in the materials used for these processes.

This paper will summarize some of the factors affecting the choice of materials, difficulties encountered in their actual use, and some examples of the effective utilization of the specialized properties of some materials.

Factors Affecting Materials Selection

Cost Factors

The purchaser of photographic processing equipment must be concerned with the associated initial and operating costs. These will be dependent to a considerable degree on the materials used in its construction. Contributing to initial cost are the type and quantity of

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materials used, the effort required in fabrication and assembly, and the cost of installation of the assembled equipment.

Operating costs will depend on: reliability in use, and those elements of the design affecting ease of operation; maintenance, such as ease of cleaning, required adjustments, and need for painting; and durability influenced by resistance to breakage, wear, corrosion, and deformation.

Quality Factors

The user of photographic processing equipment must be concerned with the effect of the materials used on the resulting quality of the film or paper processed. Both physical and photographic quality must be considered.

Effects detrimental to photographic quality are stain of the emulsion layers or support, and various evidences of improper development such as fog which may be attributable to the presence of copper, tin, or sulfur compounds. Improper development may also be evidenced as density suppression, contrast mismatch, speed shift, or distortion of curve shapes.

Physical quality may be impaired because of dirt from wear particles and corrosion products such as Prussian Blue; or as the result of abrasive contact with rough surface finishes on machine parts, or with well finished surfaces that are susceptible to becoming embedded with abrasive particles.

General Considerations

Most commercial materials that have suitable characteristics for use in processing equipment are more expensive than those used for general industrial applications. Consequently, the advantageous use of specific materials depends upon skill and ingenuity in design, and upon a high degree of efficiency in fabrication. These considerations have led to an increasing use of plastics because of their ease of fabrication, and their wide range of desirable physical and chemical characteristics. On the other hand, the improved designs and fabrication methods applied to stainless steel, for example, have resulted in some outstandingly successful equipment constructed from this class of metallic alloys.

Before proceeding to the discussion of some specific applications, consideration will first be given to conditions affecting the use of various materials.

Effects of Processing Solutions on Metallic Materials

The physical and chemical factors affecting the deterioration of metals and alloys subject to corrosive action have been the subject of extensive research. The corrosion of metals is of such dominant economic importance that studies in this field form a voluminous literature. Only a few essential aspects of the subject will be considered here.

The chemical resistivity of a metallic alloy to a particular processing solution can readily be determined by simple laboratory tests. Serious deterioration under such conditions would strongly indicate that any similar use of the material would be inadvisable. Related to the essential chemical resistivity is the relatively severe corrosion often occurring at the line of contact of a material with an air-liquid interface.

Equally severe are the electrolytic effects due to the electrical contact of dissimilar metals in mutual contact with a chemical solution. Similarly, the concentration differences in a body of chemical solution in contact with areas of similar metal in electrical contact may give rise to electrolytic corrosion. This often occurs where pockets or crevices tend to restrict the free circulation of the chemical solutions.

The fabrication of metals may seriously detract from their resistance to corrosion. This is particularly true of stainless steels. After fabrication, stainless steel components are usually given an acid treatment commonly designated as "passivation," a term implying the generation of a protective oxide film. Actually such treatment is primarily directed toward the removal of surface metallic contamination introduced during fabrication, and as such is more correctly described as "pickling." The corrosion resulting from such surface contamination may easily be demonstrated by cleaning stainless steel surfaces with steel wool. This is most inadvisable on valuable equipment because corrosion will occur wherever steel particles become embedded during the "cleaning" process.

Resistance of stainless steel to corrosion may also be reduced by changes in the material as the result of welding. Such effects are usually due to changes in the structure of the metal and to the precipitation of particles of chromium carbide from the chrome-nickel-iron alloy. Effects of welding may be minimized by the choice of proper stainless steel alloys, and by the use of approved welding procedures.

The presence of severe mechanical stresses in a material as the result of fabrication will also influence its susceptibility to corrosion. Such effects are apparent at areas of maximum stress. Proper annealing treatment will relieve locked up stresses due to fabrication, thereby avoiding such susceptibility to corrosion.

Other factors affecting corrosion of metallic components in processing machines are the frequency and duration of exposure to such solutions as bleaches. It is common practice to carry films through ferricyanide bleaches with stainless steel hangers. No serious corrosion of the hangers usually results. However, contact with ferricyanide bleach for an extended period would cause severe damage to the hangers.

The accumulation of surface deposits from contact of processing solutions with metals will sometimes promote corrosive attack. This is particularly true of deposits of corrosion products. Where such effects are observed, routine cleaning procedures should be established to prolong the life of the equipment.

The effects of solution carry-over warrant special mention, since these may not be given sufficient consideration. A color processing laboratory in England recently reported difficulty due to the rapid corrosion of stainless steel machine parts exposed to the action of a dichromate bleach. Bleach solutions of this type normally have little corrosive effect on AISI #316 stainless steel. This laboratory observed that the use of a very high replenisher rate for the bleach solution lessened the corrosive action. This provided the essential clue to the identification of the basic cause of the difficulty, ex-

cessive carry-over of fixing bath into the bleach tank. Contamination with fixing bath causes a substantial increase in the corrosive action of dichromate bleaches. We have not investigated the mechanism of this corrosive action.

The selection of materials for use in contact with bleach solutions should take into consideration the possibility that the chemical composition of the bleach solution may be subject to modification in the future. Bleaches in current use in color processes for the removal of developed silver usually have little effect in reducing the density of dye images, and normally convert practically all of the silver grains to silver salts which are soluble in the fixing bath. However, it is to be expected that future improvements in bleaches will be directed toward reducing further the effects of the bleach on dye images and toward the elimination of any tendency for silver retention. Such changes may well result in an increase in the corrosive action of the bleach solutions. Consequently, materials selected for such applications should preferably provide a margin of safety against corrosive attack more severe than that associated with the existing bleach formulations.

Effects of Processing Solutions on Plastic Materials

Laboratory tests to determine the chemical resistivity of plastic materials to processing solutions are described in the references cited earlier.[1,2,3] Because of the variety of effects that may occur with different types of materials, the results of such tests must be examined and interpreted with great care. In some instances a gradual deterioration of the material may occur because of the long-term effects of processing solution additives, which have a solvent action on the plastic material. Such effects may not be apparent in laboratory tests carried out over a period of a few days or weeks.

The fabrication of plastic materials may reduce their durability when exposed to chemical solutions. In the case of thermosetting plastics, incomplete or improper curing may result in less suitable properties of the material. Plastics of this class sometimes have properties sensitive to conditions of the polymerization treatment. As a result, it is sometimes found that apparently identical parts made from the same batch of material will differ in their chemical resistance. Also, improper molding may result in an excessive porosity of the plastic, which would permit an increased penetration of solution within the material. Molding may also fail to produce an adequately smooth and hard surface finish, thus resulting in an increased tendency to wear and in a greater penetration of solution within the material. Improper fabrication may also result in locked-up stresses. Such a stressed condition may relieve itself over a period of time, or may be relieved by the effects of increased temperatures or solution penetration, in either case resulting in a deformation of the original shape to a point where the part may no longer be usable.

Plastic materials may also be affected in other ways. A gradual loss of plasticizer may cause a reduction in strength or resistance to breakage. The moisture absorption of some plastic materials will proceed rapidly over a short time, and then reach an equilibrium condition beyond which no further absorption occurs. Other materials may take up moisture very slowly but over a long period of time. These effects must be carefully predetermined before specifying the dimensions of finished parts since important dimensional changes may be associated with the absorption of moisture.

The effect of elevated temperatures on plastic materials may be to relieve stresses as previously mentioned or to cause a deformation of thermoplastic materials even though the temperatures are somewhat less than those that would cause appreciable softening. Some materials have a well defined softening point below which plastic deformation will not occur; other have a longer softening range, permitting deformation of the material at temperatures well below those used for fabrication.

Many clear plastic materials are subject to staining on prolonged contact with processing solutions. This may not affect the strength or durability of the plastic, but may greatly detract from its appearance. Staining is, of course, particularly objectionable where clear plastic materials are used to provide ready visibility of solutions or processing operations.

The frequency and duration of exposure of plastic materials to processing solutions have a marked effect on those plastic compositions subject to mild attack. Those conditions that limit the extent of moisture penetration, by permitting drying intervals, limit the depth of attack or dimensional change that may occur. Some materials not satisfactory for long-term immersion will not be subject to serious deterioration when exposed intermittently.

The wear characteristics of plastic components in processing equipment may be affected by a variety of conditions. The most important of these is the presence of water as a lubricant. Although some plastic bearing compositions may perform best in a dry state, water-lubricated plastic bearings are generally more satisfactory. Rubbing surfaces will incur a minimum wear when one tends to polish the other. This is often the case with water-lubricated plastic bearings running against metal shafts. Bearing failure and extreme wear will occur when a galling action takes place, resulting in a tearing of the surfaces of the shaft and bearing. These galling effects are sometimes difficult to predict or analyze. Galling of plastic bearings is best avoided by the use of a matrix of fibrous material which serves to break up any surface contact into individual small areas. Such areas of plastic have a maximum polishing action on metal shafts together with minimum tendency to galling. Impregnates and laminates in most cases have superior wear characteristics.

Contamination of Processing Solutions as the Result of Contact with Constructional Materials

Solution contamination as the result of contact with the materials used in processing equipment depends on a number of factors. Most important is the presence of photographically active compounds of copper, tin, or sulfur; or organic compounds having groups affecting the processing characteristics of photographic films and prints. Copper may be present in valves or piping. Tin is most likely to be present in soldered joints or seams. Sulfur compounds are commonly introduced as the result

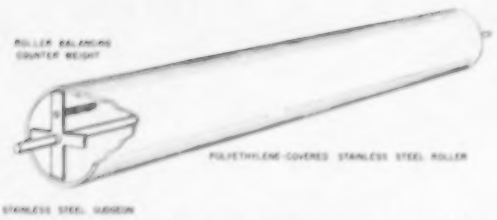

Fig. 1. Diagram of bottom roller on processing machine for color prints

of contact with rubber compositions encountered in pumps or connecting hose. For some extremely sensitive photographic applications it may be necessary to specify "sulfur-free rubber." Such materials have relatively poor mechanical properties. Rubber compounds specified as containing "no free sulfur," or as "pure gum rubber" are usually satisfactory for use in contact with processing solutions. Photographically active organic materials are sometimes introduced from improperly compounded or insufficiently cured thermosetting plastics.

Equally important are factors such as the area of the contaminating material presented to the solution compared to the total volume of the solution, and the time interval of this contact. Some vessels used during processing are fabricated from sections of stainless steel sheets joined with seams sealed with solder. Prolonged contact of photographic developers with large areas of solder causes these developers to fog photographic emulsion coatings. However, the very small area of solder required to fill a locked seam, and the relatively short time that solution need remain in a processing tank for intermittent use makes such vessels usually acceptable for processing. Developing solutions should not, however, be stored in such containers.

Some plastic materials tend to absorb developer additives that are active solvents for the plastic. The absorption of these additives by plastic can be accompanied by the absorption of developing agent. Such effects are usually most rapid when fresh areas of the plastic are exposed to the solution. The effects often become negligible after a period of seasoning. There is, however, no certainty that these effects will diminish after extended exposure.

The area of contaminant presented to the solution may be effectively increased by the discharge of fine wear particles into the solution, or by the effect of pores in the material presenting a large area of contaminant relative to the total solution volume. Porosity may also permit increased oxidation of contained solution when materials having a microscopically-fine, porous structure are used as containers for solution storage.

Examples of Materials Applications

Limitations of Plastic Hose

The first example concerns a particularly unsatisfactory experience in the use of plastics. A processing machine had been used for experimental trials using batch replenishment. In the course of these experiments it was required to convert to continuous replenishment, necessitating a new supply line to the developer storage tank. Rather than install a permanent stainless steel line it was expedient to run a 50-foot length of plastic hose from the tank to the machine.

The results were suprising. The developer supplied to the machine at the required, very low replenisher-rate had barely any development effect. Chemical analysis showed that the solution in the storage tank was normal. However, analysis of the solution supplied through the hose to the machine revealed that:

(1) Developing agent had been removed almost completely from the solution.
(2) A solvent additive in the developing solution had also been completely removed.
(3) Plasticizer from the plastic hose had been extracted into the solution.

Subsequent tests showed that these effects diminished slowly with prolonged contact of the tubing with the developing solution.

These tests and further investigation led to the conclusion that at least some plasticized materials should not be used in prolonged contact with developing solutions containing such solvent additives. However, their use might be permissible provided that the tubing is given prolonged seasoning treatment, and that both the ratio of area-of-plastic to volume-of-solution and the time of contact of plastic hose with developing solution are sufficiently small. Recent installations of similar machines use a more resistant polyvinyl chloride hose instead of the plastic tubing chosen initially for the developer supply line.

Metallic Corrosion

Another type of difficulty is that encountered when processing solutions stand in centrifugal pumps. Stainless steel pump shafts sealed with graphitized packing often are subject to a corrosive roughening of that portion of the shaft in contact with the packing. This usually occurs when such pumps are left standing for a week or more, filled with solution. This corrosive effect was formerly attributed to electrolytic action associated with the graphitized packing. The effect is now believed to be primarily due to changes in concentra-

Fig. 2. Bottom rollers on processing machine for color prints

tion that may occur in the solution along the area of contact of the shaft and packing. Running the pump for short intervals every few days is usually sufficient to prevent any such corrosive action. Such corrosion may also be avoided by the use of a more expensive construction employing a graphite-carbon mechanical seal. Here the rubbing surfaces are not susceptible to corrosion. Intermediate in cost would be the use of a shaft made of Hastelloy "C," which has a higher corrosion resistance than stainless steels.

A diagram is shown in Figure 1 of a bottom roller used in continuous machines for the processing of color prints. These rollers are free-running idlers, driven without slippage by frictional contact with the emulsion surface of the color print material. A balancing rod is welded inside the roller to compensate for any unbalance after fabrication. The length of the rod is selected to suit the degree of unbalance. After a period of use it was found that the rods in many of these rollers had been badly corroded. Investigation revealed that the rod stock actually used was a metal dissimilar to the rest of the roller assembly. The resulting electrolysis caused severe corrosion of the rods, even though the processing solutions were only mildly corrosive to the rod-stock alone.

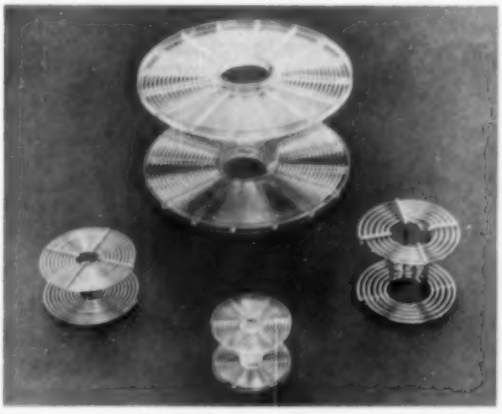

Fig. 3. Processing reels of plastic and stainless steel

Frictional Characteristics

A high frictional-coefficient is desired between the surface of such rollers and the emulsion layer of the print material, since any slippage is likely to cause scratches of the emulsion surface. The engineers directly concerned with the operation of these machines found that a hot-spray coating of polyethylene on the roller surface eliminated the slippage frequently experienced with other materials.

Figure 2 is a photograph of one of these rollers, and of the wood and stainless-steel rollers previously used. At the ends of the shafts visible in the photograph are bearings designed to present minimum resistance to rotation. For a number of years the bearings used consisted of a phenol-formaldehyde laminate that afforded good wear characteristics but had a moderately high frictional resistance. Bearing blocks of solid tetrafluoroethylene were substituted to obtain reduced friction. These

Fig. 4. Resistance welded stainless steel drum and polyvinyl chloride drum

wore rapidly, although the same material under somewhat similar test conditions wore scarcely at all. These machines have since been equipped with bearings of an asbestos-tetrafluoroethylene impregnate which has good wear characteristics along with low friction. Very recently another material consisting of Fiberglas impregnated with a mixture of tetrafluoroethylene and molybdenum disulfide appears to have even lower friction and better wear resistance.

Thus, one assembly includes two applications of plastics, one to obtain a maximum contact-friction between the roller and the color print material, and the other to provide a minimum bearing-friction on the shafts of the rollers.

Ease of Fabrication

A number of reels used for photographic processing are shown in Figure 3. As might be expected, molded plastics are an excellent means of obtaining forms so difficult to fabricate. The large plastic reel of impact-resistant polystyrene is used for 25-foot lengths of paper prints; the small plastic reel is an experimental model for rolls of film. The stainless steel reels shown here are an example of how good design and efficient fabrication can utilize this material to provide, at low cost, good durability and functional suitability.

Figure 4 illustrates a fabrication method used on commercial stainless steel drums. Here, a light-gauge sheet is resistance-welded to provide a strong mechanical joint with a liquid-tight seal. Such joints must be carefully designed and fabricated to avoid crevices that would be a primary source of weakness to corrosive attack by the contained solution. Also shown is a similarly shaped drum, made of polyvinyl chloride, used for bleach solutions.

Minimum Maintenance

A panel construction, shown in Figure 5, illustrates the use of plastic-surfaced composition board. Previously, panels used to light-lock sections of processing machines required frequent painting and were, in any case, a source of dirt. The panel shown has a phenol-formaldehyde laminate surface, much the same as that used on some

Fig. 5. Plastic-surfaced panel for light lock in a processing machine

table tops. The resulting cleanliness and the lack of any need for painting have justified the slightly higher initial cost of the material. The machine shown is used for processing 35mm color motion-picture film.

Durability

Such machines require a large number of rollers for conveying the film. Samples of these rollers of various sizes and materials are shown in Figure 6. Hard rubber was first widely used for this purpose and then phenol-formaldehyde compositions were preferred, although both were subject to breakage because of their brittleness. More recently, molded polyamides and polyvinyl chlorides have been widely adopted. Both provide excellent properties for many applications. Difficulty has sometimes been experienced with polyamides, such as some Nylon compositions, because the designer has failed to appreciate that while this material may swell slowly because of its low rate of moisture absorption, this absorption and the resulting swelling may continue for as long as several months. Consequently, some processing machines have jammed after months of successful use when swelling has taken up all of the running clearance initially provided. Proper allowance for ultimate swelling is one of the few restrictions in the use of polyamides in processing applications. The same restriction applies to phenol-formaldehyde laminates, samples of which are shown. Other rollers pressed from thin stainless steel are also used; although these are slightly more expensive, they are particularly desirable for some special purposes.

Protective Layers

A recently developed combination employs a thick overlay of impregnated Fiberglas on a marine plywood support. This construction affords particularly low cost in the fabrication and assembly of tanks. The impregnant is a type of epoxy resin selected for this application. Polyester resins are also used in Fiberglas impregnates. These, too, have good mechanical properties and corrosion resistance when exposed to some processing solutions.

The protection afforded by very thin layers is notoriously unreliable. Electroplated metallic coatings usually suffer from porosity, which ultimately results in blistering and pitting from corrosion of the underlying material. Paint layers have in the past proved unsatisfactory. Improved paints, in the absence of severe mechanical abrasion, have recently appeared to give more satisfactory protection. Surfaces protected by ordinary paints usually limit the useful life of the equipment. Rubber-lined steel tanks often rust out as the result of corrosion through the outside painted surface. For processing machine applications it is often good economy to make the additional investment required to have the rubber lining extend over the outside surfaces as well as the inside.

Various Uses of Plastic Materials

It is pertinent to mention at this point that it is not sufficient to specify plastic materials for a particular application purely in terms of their general classification. Many manufacturers list a number of materials within a given classification, each with its own code number and range of properties, and designed for specific uses. In selecting material for a given application it is necessary that, not only the material type, but the manufacturer's code number be specified if difficulty is to be avoided. In many cases this may be merely a prudent precaution. For at least a few types of materials it is a positive necessity. In the case of metallic alloys, general trade specifications apply to those types most commonly used. This is the case for the various stainless steel alloys.

Polyethylene containers are used to an increasing extent for photographic solutions. Such containers have the desirable characteristics of lightness, low cost, resilience, and strength. Those which are at present commercially available have shown a susceptibility to oxygen penetration owing to microscopic porosity of the material. Photographic developers stored in small containers of polyethylene will be subject to oxidation effects greater than would be encountered with storage in full glass bottles. Large containers have a sufficiently small surface-to-volume ratio so that oxidation effects may not be apparent over a moderate period of storage. These effects are sufficiently small that oxidation prevention through the use of a floating cover on storage

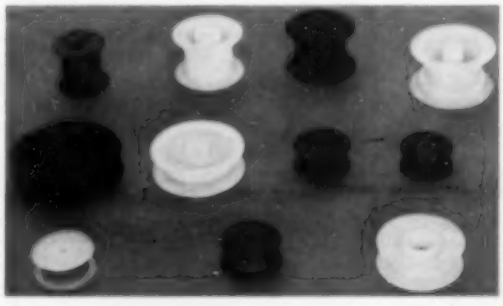

Fig. 6. Samples of rollers used in motion picture processing machines

tanks is probably more important than the lesser effect due to the oxygen permeability of the material.

In Figure 7 are shown parts formed, under heat and vacuum on a wood mold, from unplasticized polyvinyl chloride sheet. The ease of this fabrication method permits the economical production of complex forms that have excellent corrosion resistance and no apparent contaminating action in contact with most processing solutions. Formed shapes and panels of this material are often heat-welded. Polyvinyl chloride parts should not be exposed to excessively high temperatures owing to their thermoplastic characteristics. Unplasticized polyvinyl chloride, sometimes designated as "rigid," has found wide use for the piping of processing machines. Its inertness, strength, and resilience make it particularly suitable for such applications.

Many widely used processing machines of recent design, such as some built by DeBrie, Arnold and Richter, and Houston, are constructed predominantly of plastics. In contrast, one example of modern stainless steel construction, shown in Figure 8, is a machine built by Artisan Metal Products. The functional design of this spray processing machine for motion picture film is a good example of the effective use of stainless steel to obtain simplicity of fabrication and ease of operation. This machine was recently described to the SMPTE at the New York Convention.

Fig. 7. Parts formed from polyvinyl chloride sheet

Conclusion

For many applications either metals or plastics may be advantageous depending on the specific selection of material, the design chosen, and the method of fabrication. For some purposes a construction entirely of AISI #316 stainless steel will afford the maximum durability, cleanliness, and versatility. In other applications an all-plastic composition may be preferred.

Any user of processing equipment will benefit from a full knowledge of the properties of the materials useful for his requirements. Such knowledge will enable him to obtain the maximum use of his equipment at minimum operating cost, and at the same time provide the most acceptable physical and photographic quality in his processed film and prints. A list of the more commonly used materials will be found in the appendix to this paper.

The author wishes to acknowledge the considerable information included in this paper contributed by Dr. Lloyd E. West and Mr. W. R. Weller of the Color Technology Division and Mr. H. H. Brown of Engineering, Construction, Maintenance and Utilities of the Eastman Kodak Company

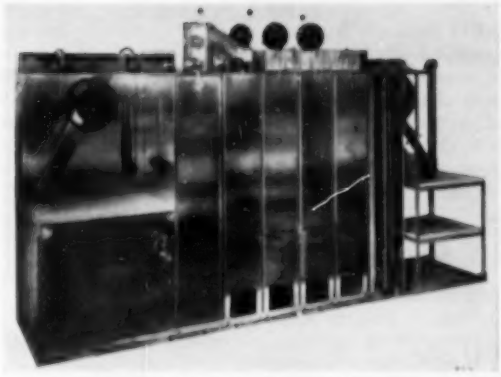

Fig. 8. Commercial processing machine constructed of stainless steel

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1. L. E. Muehler and J. I. Crabtree, Materials of Construction for Photographic Processing Equipment. PSA Journal, Vol. 19B: pp. 79-88, May; pp. 92-104, August, 1953.

2. American Standard Methods and Criteria for Determining the Chemical Resistivity and Photographic Inertness of Constructional Materials for Processing Equipment. American Standards Association, Incorporated, New York, N. Y. PH4.13-1954.

3. Bernard A. Hutchins, The Testing of Plastics for Use in Contact with Photographic Processing Solutions. JSMPTE, Vol. 65: pp. 227-229, April, 1956.

Appendix

The problem of materials selection for a specific application may be approached in two ways: some may choose to make a detailed study of a wide variety of materials in search of a unique advantage in cost or operation; others will prefer to rely on the long-term experience which has been accumulated in the performance of various materials for similar uses.

The following summary of materials practice is intended to include only those in most general use. To include all possible choices would be confusing, and possibly even misleading. In broad usage some selections will have been based on specialized requirements, others on personal preference. It will be understood that for some purposes other materials than those specified will be equally suitable, and may possibly in special instances be preferable.

SPECIFIC MATERIALS FOR PROCESSING EQUIPMENT

Processing Machine Tanks—Large Tanks

(1) Type 316 Stainless Steel—Welded.† For all stages except:
(a) ferricyanide bleaches and others with similar corrosion action
(b) the stage following a ferricyanide bleach
(c) some fixing baths of specialized composition having a corrosive effect on Type 316 Stainless Steel

(2) Rubber*-Lined Steel (outside surface also covered). For ferricyanide bleach and following stage

(3) Unplasticized Polyvinyl Chloride.* For ferricyanide bleach and following stage

(4) Red Brass (85% or higher copper content). For ferricyanide bleach and following stage (The protective film formed on red brass by ferricyanide bleaches is not resistant to abrasion. Frequent cleaning or mechanical wear is to be avoided. The initial exposure of red brass to ferricyanide bleach will often result in the formation of a black surface deposit along with the protective film. Wiping over with a soft cloth removes this deposit. After such wiping the deposit does not usually recur.)

Processing Machine Tanks—Small Tanks

(1) Unplasticized Polyvinyl Chloride.* All stages
(2) Type 316 Stainless Steel. Except as noted above
(3) Epoxy* Resin Compositions or Impregnates. All stages
(4) Hard Rubber. All stages
(5) Polyethylene.* All stages

Processing Machine Roller Shafts

(1) Type 316 Stainless Steel. Except as noted above
(2) Hastelloy "C." For ferricyanide bleaches and following stage

Processing Machine Cine Film Rollers

(1) Molded polyamides* (Nylon resins)
(2) Molded unplasticized polyvinyl chloride*
(3) Pressed Type 316 Stainless Steel sheet stock. Except as noted above

Processing Machine Wide Film or Paper Print Rollers

(1) Polyethylene* hot spray coating on metal tubing (Special procedures required)
(2) Unplasticized polyvinyl chloride tubing*

Bearings for Shafts and Rollers in Processing Solutions
Sleeve Bearings

(1) Asbestos—tetrafluoroethylene* impregnates (Rulon A)
(2) Fiberglas—tetrafluoroethylene*—molybdenum disulfide impregnates
(3) Phenol-formaldehyde laminates

Ball Bearings

(1) Type 316 Stainless Steel. Except as noted above
(2) Glass balls—plastic races

Gears Running in Processing Solutions

(1) Type 316 Stainless Steel running against mating gear of phenol-formaldehyde laminate or composition. Except as noted above
(2) Type 316 Stainless Steel running against mating gear of molded or cut polyamide.* Except as noted above
(3) Molded or cut polyamide* mating gears

Rack Frames Used in Processing

(1) Type 316 Stainless Steel. Except as noted above
(2) Rubber*-covered steel. Ferricyanide bleach and following stage
(3) Phenol-formaldehyde laminates. Ferricyanide bleach and following stage
(4) Red Brass—85% or higher copper content. Ferricyanide bleach and following stage

Film Clips and Hangers

Types 302, 304, 316 Stainless Steel depending on solution corrosiveness, immersion time, and method of fabrication

Weights for Film Clips

Lead—98% or greater lead content
4–8% antimony content improves strength but tends to plate out silver from fixing baths in powder form. This is discharged into solutions and tends to be deposited on the emulsion and support surfaces of films being processed.

Solution Handling Equipment

Large Mixing and Storage Tanks

(1) Type 316 Stainless Steel—Welded.† Except ferricyanide bleaches and some fixing baths
(2) Rubber*-Lined Steel (outside surface also covered). For bleaches
(3) Unplasticized polyvinyl chloride.* For bleaches

Small Mixing and Storage Tanks

(1) Type 316 Stainless Steel—Welded.† Except as noted above
(2) Unplasticized polyvinyl chloride.* All solutions
(3) Polyethylene.* All solutions

Solution Pumps

(1) Type 316 Stainless Steel. Except as noted above
(2) Cast iron. For developers only
(3) Hastelloy "C." For ferricyanide bleaches
(4) Durichlor—(Hastelloy "C" shaft). For ferricyanide bleaches

Rigid Piping for Low Pressures

(1) Type 316 Stainless Steel thin tubing—compression or flange fittings. Except as noted above
(2) Unplasticized polyvinyl chloride* tubing—compression fittings. (Provision should be made for thermal expansion of this material and for structural support except for short lengths)

Rigid Piping—Medium Pressures (for filtration, etc.)

(1) Type 316 Stainless Steel threaded piping—screw or flanged fittings. Except as noted above
(2) Rubber*-Lined Steel. Flanged piping

Flexible Piping—Low Pressures—Supporting structure required except for short lengths

(1) Polyvinyl chloride* tubing
(2) Neoprene* tubing
(3) Pure gum rubber* tubing

Flexible Piping—Medium Pressures—Supporting structure required except for moderately short lengths

(1) Neoprene*-lined pressure hose
(2) Rubber*-lined pressure hose

* Material recommended by the manufacturer to be of suitable composition for the specific conditions of use.

† Specific precautions are necessary in the welding of stainless steel for corrosive applications, and in the associated fabrication operations. Equally important are proper maintenance procedures. These subjects have been discussed in detail by H. H. Brown as a part of the paper by Muehler and Crabtree[1] previously mentioned.

PRINTING THE COLOR NEGATIVE

Val R. Pieronek, Warren L. Syverud, and William F. Voglesong*

ABSTRACT

The problem of printing color negatives is discussed as it applies to the operations of amateurs and of small-scale, and large-scale photofinishers. Tri-color and white-light, intensity- and time-variation printing are reviewed. A sample of normal color negatives is examined as it discloses the need for negative classification, color correction, and the application of lowered-correction printing. The utility of slope control is described. The setting up, operation, and control of the Kodak Roll Paper Color Printer, Type IVC, are outlined. A practical problem of printing yields is posed and analyzed.

THE PRINTING of black-and-white negatives has been the backbone of photography almost since its beginning. In considering the rather formidable problem of printing the color negative, it might be encouraging to note that this too has been done successfully and on a commercial scale in at least three operations: the motion picture industry, the Agfa and Ansco negative-positive color processes, and the Kodacolor Print program. Negative-positive color printing is an accomplished fact. A comprehensive treatment of the problem, however, would be outside the scope of this article. Here we consider the problem of printing the color negative as it confronts the color photofinisher, largely in terms of printing the Kodacolor negative on Kodak Color Print Material, Type C. The principles discussed, however, are general and should be applicable to a reasonable extent to other processes as well.

Perhaps the simplest and most direct way in which a Kodacolor negative may be printed on Type C Paper is to place the negative in contact, emulsion to emulsion, with a sheet of Type C Paper, beneath a suitable light source. The exposure level of the print may be controlled by the duration of the exposure, and the color balance may be adjusted by means of color-compensating filters placed in the light beam. With some experience a pleasing print should be obtainable, by trial and error, on the second or third printing.

By placing the negative in an enlarger and projecting the image on the paper at a preferred size, the operator avails himself of a more flexible and convenient system of printing. Almost any enlarger equipped with a tungsten lamp, and preferably a heat absorber, will do. Enlargers with fluorescent lamps may also be used but are usually less satisfactory because the spectral deficiencies of the light source necessitate relatively long exposure times. Again the approach to a satisfactory print is empirical, but the operator may be able to take advantage of some very helpful and more specific information from the paper manufacturer to help him obtain a more satisfactory first print. This he then may adjust by trial and error to his requirements. For instance, users of Type C Color Paper are supplied with the following additional information for the Kodak Autofocus and the Kodak Flurolite Enlargers:

Tungsten	*Fluorescent*
Kodak Autofocus Enlarger	Kodak Flurolite Enlarger
Kodak Wratten Filter No. 2B	Kodak Wratten Filter No. 2B
Kodak Color Compensating Filters	Kodak Color Compensating Filters
CC-30R	2-CC-50R
CC-05R	CC-30M
CC-20M	
CC-10Y	

With these starting filter-pack recommendations much of the trial-and-error effort in determining color balance has been reduced.

A further suggestion is included as to the first guess about the exposure time. With the Autofocus Enlarger, for instance, when a $2^1/_4 \times 3^1/_4$ Kodacolor negative is enlarged to an 8×10 print, the lens may be set at f/8 and an exposure time of 20 seconds might be a reasonable guess.

These directions are in terms of a specific enlarger, but they may also serve as a useful guide for work with other enlargers of similar design.

Although we may speak presently of some much more sophisticated and complicated printer designs, the enlarger setup just described is still the simplest and most practical method of printing, where only one or a very few prints are to be made for casual amateur use. Even when a larger group of negatives is printed, if the negatives are related, such as similar exposures on the same roll, the printing exposures required should be reasonably similar differing probably by no more than a CC-10 filter, and exposure continues to be a relatively minor problem.

Prejudging the Color Negative

In commercial photofinishing, however, the printer operator is usually confronted with a larger variety of negatives of widely differing characteristics. If he were to attempt to print each by trial and error, he would find that the time involved and the waste factor would be prohibitive. At this point, commercial negative-positive color printing would find itself at a serious impasse were it not for the fact that effective methods have been found for interpreting and relating color negatives by automatic or semiautomatic physical measurement. These methods are sufficiently efficient to be the bases for large and successful negative-positive color printing operations.

The color timing method in current use in the Kodacolor Print program is based on a U.S. Patent 2,571,697 granted to Ralph M. Evans in 1951. According to

* Color Technology Division, Eastman Kodak Company, Rochester 4, New York. Presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York 26 May 1956. Received 1 October 1956.

present practice, once the exposure has been determined by trial and error for a representative negative, it is possible to predict the exposure of reasonably similar negatives by measuring the red, green, and blue transmittances of their entire areas and comparing these transmittances with those of the original negatives. The system is based on the assumption that the red, green, and blue transmittances of average negatives are nearly constant and will, therefore, integrate to a constant hue. If the total integrated transmittance of the second negative varies from that of the first, a change in exposure corresponding to the difference in transmittance of each of the red, green, and blue components will correct both the density level and the color balance in one operation.

Figure 1 shows three Kodacolor negatives differing somewhat in subject matter and in color distribution. If the total light transmitted by each negative is integrated and used to print a uniform patch as shown in the second row, the color- and density-level match among the three patches indicates that the integrated exposure beam from each negative was of about the same spectral composition and of about the same intensity. This suggests that the same printing exposure could be used to produce a satisfactory print from each of the negatives. Prints made from each of the three negatives with the same exposure time are shown at the bottom of Figure 1.

Figure 2 shows three other Kodacolor negatives. To the untrained eye they might appear to be very similar. If it were assumed that these required the same exposure and all three were printed under the same exposure conditions, the set of prints shown in column 2 might be obtained. All three are significantly different in color balance. The total integrated transmission of each of these three negatives can be evaluated by printing a uniform patch from each. It is evident that unlike the patches seen with the three previous negatives, these patches differ not only in over-all density level, but also in color balance. Instead of printing such color patches, a suitable photoelectric cell and meter may be placed in the light beam where it will be possible to measure the integrated red, green, and blue transmittances of each negative. By means of these measurements it is possible to predict the changes in exposure, which would be required, so that the total light of each color passing through each negative would be the same. When the exposure changes predicted by these measurements are made, the resulting prints appear as in the last column in Figure 2. This, essentially, is the principle of the color timing procedure used in Kodacolor printing.

The Variety of Color Negatives Encountered by the Color Photofinisher

Experience shows that a representative sample will contain a variety of negatives. They may differ in:

1. subject matter
2. camera exposure
3. type of illumination
4. manufacturing and storage history of film
5. keeping conditions of latent image, and
6. processing conditions.

If one looks more closely at a current sample of negatives, he will see one immediately apparent difference among them: some negatives will have a characteristic yellow-orange color, while others will show a reddish orange. It so happens that the new CU Type Kodacolor Film has the reddish-orange balance while the earlier T-2 Kodacolor has the yellow. It will be found with experience that each of these two film types requires a somewhat different printer balance. It would be best to sort the color negatives at this point and print each type separately. It will also be found that within the CU Type film, the indoor exposures, as a group, will require a printer balance somewhat different from the outdoor. It would be well to sort the negatives with the pink-orange cast into indoor and outdoor exposures as disclosed by the subject matter. As will be shown later, each group can be handled very conveniently on a production line printer for Type C material, which provides three different printing balances for this purpose.

Color Timing

Begin by selecting from each group the most normal or average of the negatives and determining the proper exposure for it by trial and error. Such a normal or "standard negative", as it is more often called, can also be purchased for the purpose. Three standard negatives are currently available, one for each of the three classes of film.

Then read the total integrated red, green, and blue transmittances of the standard negative and of all the other negatives that are to be printed. This may be done, as is proposed for motion picture printing, in a special large-area transmission densitometer as a separate operation, or it may be done more conveniently, as in the Kodak Model E Enlarger converted for color, by placing the cell directly under the lens and reading the integrated light beam successively through the proper red, green, and blue filters. It is now possible to relate each successive negative to the standard negative and predict an exposure for it. Such predictions for color balance may be expressed in terms of color-compensating filters, or, inasmuch as the negative, in effect, has been separated into its red, green, and blue components, one may choose to control each of the three components independently. In other words, there is a choice between printing with tinted white light in one exposure, or with separate tri-color exposures. These are also known as subtractive and additive systems of exposure. Both are used and both have their proponents. While printing with white light modified with color-compensating filters usually gives a satisfactory print, it does not give the highest obtainable color quality. While these differences may not be critical for large-scale photofinishing, they may be of real significance to critical professionals and advanced amateurs. More often, however, another practical aspect must be given consideration: the tri-color or additive printer may also be easier to build and more flexible in operation. The Model 1599 Kodacolor Printers in use at Kodak Park, the Kodak Roll Paper Color Printer, Type IVC, and the Kodak Autofocus, Model E Enlarger with color conversion kit for Type C are all tri-color rather than white-light printers.

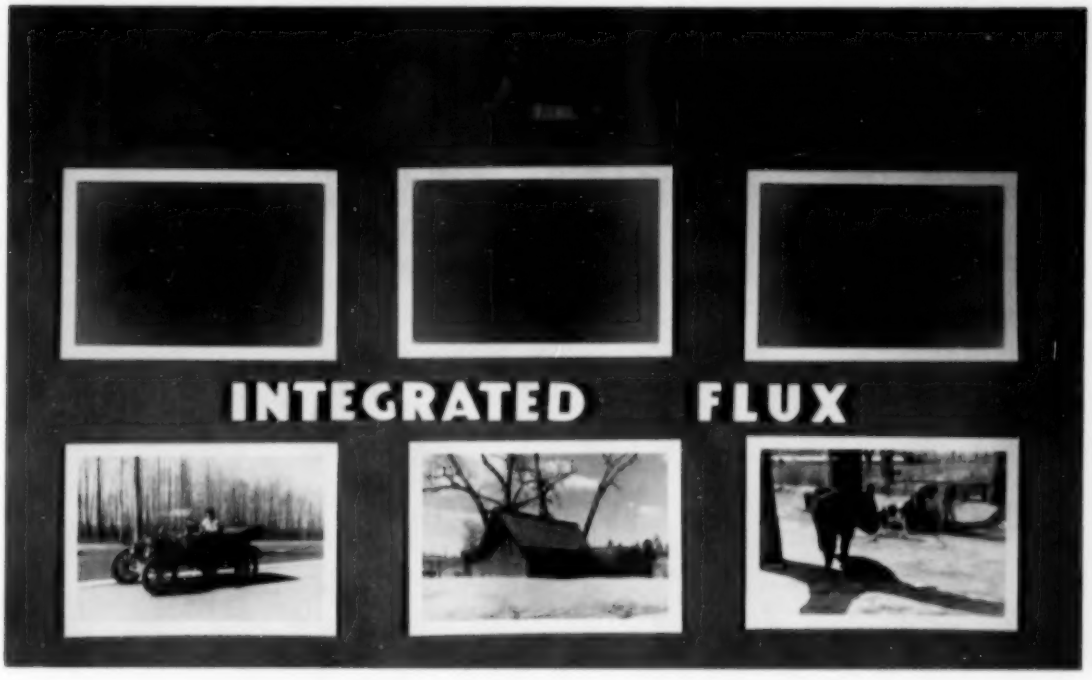

Fig. 1. Different Subject Matter, Same Printing Exposures

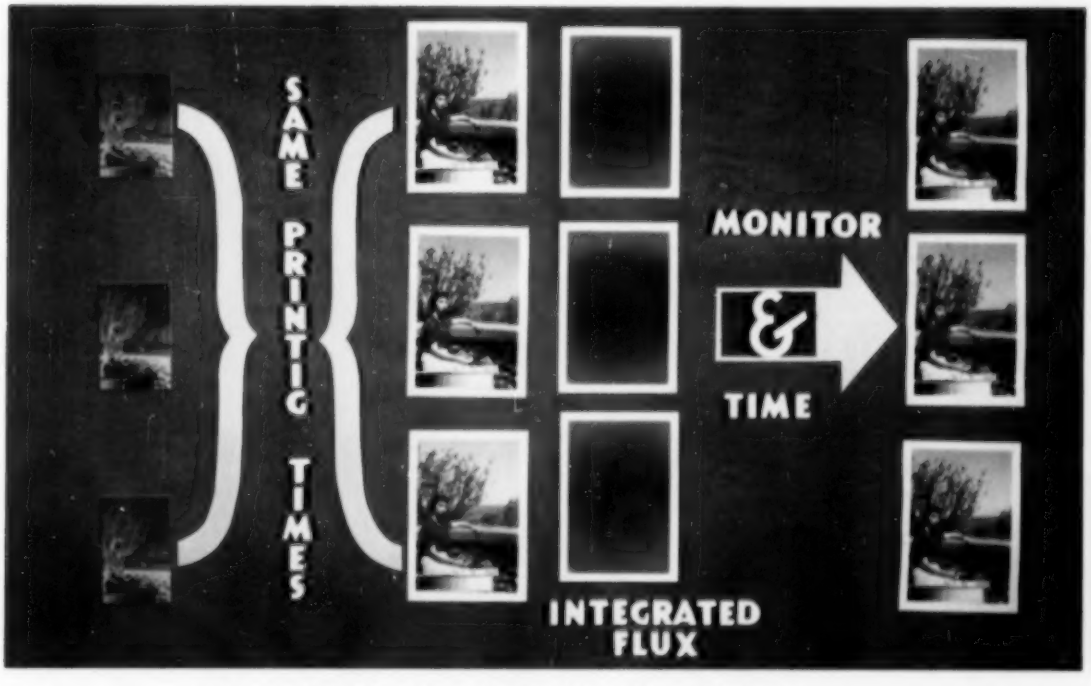

Fig. 2. Same Subject Matter, but Requiring Different Printing Exposures

Fig. 3. Subject Failure for Density: Effect of Classification in Printing

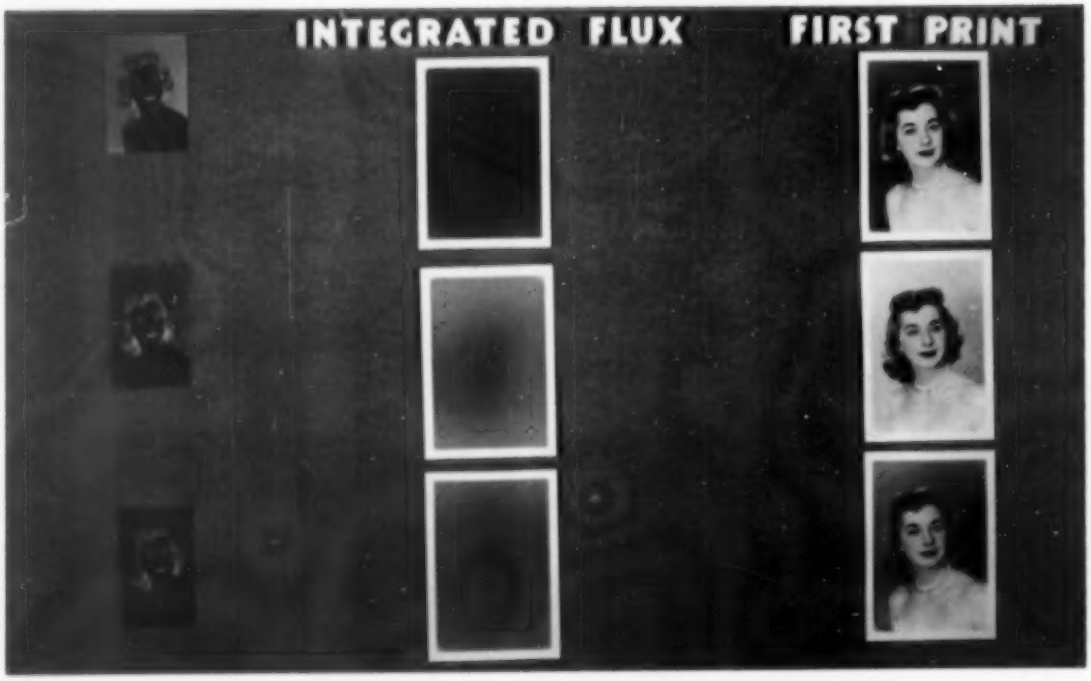

Fig. 4. Subject Failure for Color

Fig. 5. The Approach to the Problem of Color Printing

Fig. 9. Slope Mismatch: Poor Correction in Magenta

Fig. 13. Separation of Unsatisfactory Production into Groups

Fig. 14. Correction Applied to Unsatisfactory Production

Exposure Control

Whether printing with one white-light beam, or with three separate color beams, one must control the exposure either by varying its duration or by varying its intensity. According to the reciprocity law, the amount of exposure is the product of the light intensity times the duration of the exposure. While this may hold over a reasonably normal range of time and intensity combinations, photographic emulsions often have different sensitometric characteristics, such as speed and contrast, when the exposure times are either very short or very long. This is commonly known as "reciprocity failure". The possibility of reciprocity failure must be given very careful attention when a time-variation printer is designed. In the case of the Type IVC Printer and Type C Paper it was a question that received very careful attention. The IVC printer is designed to keep this problem under control. In another type of printer, known as the intensity-variation printer, the exposure time is held constant and the exposure level is adjusted by varying the intensity of the lamp. This has at least one disadvantage in that the same and relatively longer exposure time must be used for printing the normal and thin negatives as is used for the very dense negatives. A time-variation printer, on the other hand, uses its lamp at maximum output and keeps its exposure cycle at a minimum. Both types of printers are in actual use in both black-and-white and color photofinishing.

Irrespective of the particular system of printing that may be selected from those just discussed, consider what happens as printing begins with an average sample of commercial color negatives. Guided by the measurement of the total integrated transmittance of each negative, one gets very satisfactory prints from a large number of negatives on the first printing. There is, however, also a significant number of negatives that may give prints that are something less than acceptable. A look at these unacceptable prints as a group, may show that in very many of them the subject of principal interest is either very much darker or very much lighter than the surround. Obviously, when the total transmittance of such negatives is integrated, the effect of the surround is to bias the monitor in the printing system so that the monitor tends to compensate for the extreme characteristics of the surround, at the expense of optimum exposure for the principal subject.

Possible Complications

Consider these two extreme, but frequently occurring, examples: a single-flash exposure of a child against dark background, and another picture of a child against a background of snow. It is not unreasonable to expect that the child, in both cases, may require the same printing exposure. The integrated flux coming from the negative, as the printer monitor sees it, in the single-flash picture, shows a very large amount of light transmitted by the very light surround in the negative. The very dense surround in the snow scene negative withheld light from the monitor, resulting in underexposed and overexposed prints. What happens in fact is that the total integrated flux theory begins to fail here because of anomalies in subject matter. In ordinary laboratory vernacular, however, this is not referred to as "theory failure," but by means of some convenient semantics it has come to be referred to as "subject failure", and subject failure it has become.

The problem is a common one and is well-known and recognized in black-and-white printing. After some experience, a good black-and-white printer operator comes to recognize a subject-failure problem almost instinctively, and corrects his exposure for it as part of the first printing operation. In production-type photofinisher printing, this correction is known as "negative classification" and has been reduced, as an operation, to the simple pressing of a proper button. This is true both for black-and-white and for color printing.

Figure 3 shows seven Kodacolor film negatives that have been chosen to represent a practical range of subject failure for density. If they were all to be printed automatically as predicted by the monitor, they would produce the prints shown in the second row. An experienced operator, however, can prevent this by classifying each Kodacolor film negative almost as if it were a black-and-white negative. He has seven different exposure corrections to choose from, each represented by a different classification button, as shown in the bottom row. The three on the left decrease the exposure at three different levels as indicated, while the three on the right increase it correspondingly. When each negative has been printed at its proper classification, the resulting prints are satisfactorily matched. As shown in row 3, Figure 3, the improvement in print density level by means of proper classification is most striking in prints from the negatives at each end of the classification scale. These negatives represent extremes of density subject failure. Thus, by introducing the operator's judgment into the printing cycle through negative classification, it is possible to obtain a very much higher yield of acceptable prints in the first printing. However, there may be still some negatives which have not yielded satisfactory prints. Examination of the prints that have been made from these negatives, shows a number of curious color anomalies such as cyan babies on red blankets, magenta people on green grass, yellow children against a blue background. Generally speaking, where the subject of principal interest is surrounded by a large area of uniform color, it tends to be printed with a color complementary to that of the surround. This becomes especially noticeable where the surround is highly saturated and of a lower brightness than the principal subject.

The problem again is one of subject failure, but more specifically of subject failure due to unusual color distribution in the subject matter. It occurs where the picture is dominated by a large area of one hue. The automatic response of the printer monitor is to attempt to correct for this large preponderance of one color by shifting the exposure to neutralize it with the complementary color.

By way of illustration, assume that three pictures are made of the same subject, say a portrait of a girl. All of the camera exposure conditions will be the same except that the color of the background is varied in all three pictures. Since the principal subject in all three pictures is the same, and has received the same camera exposure in each case, it should be obvious that the printing exposure should be the same if three matched prints are to be made. This can be easily verified in printing.

Correcting for Subject Failure Due to Dominant Hue

Because a large part of each picture consists of a large area of a single, highly saturated color, different for each picture, the integrated light flux coming from each of the three negatives differs in its relative red, green, and blue composition. The difference in light flux as seen in the monitor is suggested in the integrated patches shown alongside of each negative in Figure 4. The automatic response of the monitor is to adjust the exposure time for all three negatives so that they print to the same constant balance. In doing so it tends to neutralize the background color to a gray by printing in the complementary color. This, of course, is done at the expense of the proper exposure for the principal subject.

As in the case of subject failure for density, the printer operator must again be provided with some means of applying a correction to the exposure as automatically predicted by the printer monitor. Again, a set of correction buttons can be provided, but this time a set of such buttons must be provided for each of the three primary colors. Such a set of color-correction buttons is useful not only for color subject failure, but for empirical adjustment of color balance of the print for any other reason.

Unfortunately, it is very difficult for the average operator to predict the amount of color correction by simple inspection of the negative. The proper color correction can be determined much more accurately when the first print is inspected. For this reason and because the percentage of negatives exhibiting color subject failure is relatively small, color correction is usually employed in the second rather than the first printing.

To repeat, in both cases of subject failure, for density and for color, it was desirable to use the operator's judgment to bias the printer monitor's automatic response to the differences that it observed in the integrated light flux transmitted by the negative.

It was stated that the operator could compensate for subject failure due to density in the first printing; that he could compensate for subject failure due to color at the second printing. At this point another proposal might be considered which tends to reduce both of these subject-failure problems by automatic means. This proposal states that if the printer is set so that it gives only 90 or 80 or 70 percent of the correction that its monitor calls for, a higher yield of acceptable prints will be obtained from negatives suffering from subject failure with no serious effect on the yield of prints from normal negatives. This is perhaps an oversimplification of a very interesting principle—the principle of lowered-correction printing. This principle is reviewed in more detail in a paper by C. J. Bartleson and R. W. Huboi entitled "Exposure Determination Methods for Color Printing: Concept of Optimum Correction Level".*

With the addition of color correction and with the application of the principle of lowered-correction printing, it is possible to print still another group of negatives from the original sample of customer's Kodacolor film negatives. The few negatives that remain are to a large extent negatives so extreme that they will probably never give satisfactory results. The extent to which these are to be reprinted must be decided by the economics and the quality standards of the printing laboratory. The approach to the problem of color printing may be summarized in the diagram, Figure 5. This diagram is not meant to be quantitative. It is not meant to show proportions. It is used only as an illustration of an approach. The printer is aimed at the standard negative. All the average negatives are then printed automatically by monitoring and timing. All density subject failures are included in this first printing by means of negative classification. The color-subject failures are color corrected in the second printing through color correction. By means of lowered-correction printing, it is possible to obtain a better yield of prints automatically from both types of subject-failure negatives.

Thus, starting with the problem of printing only one color negative, we can extract an ever-increasing number of satisfactory prints out of a large variety of Kodacolor film negatives by adding features to the printing system that help to meet the special requirements of each different fraction of the negative sample.

Starting with only a contact printing light source, successive additions were: enlargement, film-type segregation, monitoring, timing, negative classification, manual color correction, and lowered-correction printing. To this should also be added slope control, a feature to be discussed later in the article. It should be noted, however, that as the utility of the printing system is increased with each additional feature, we have

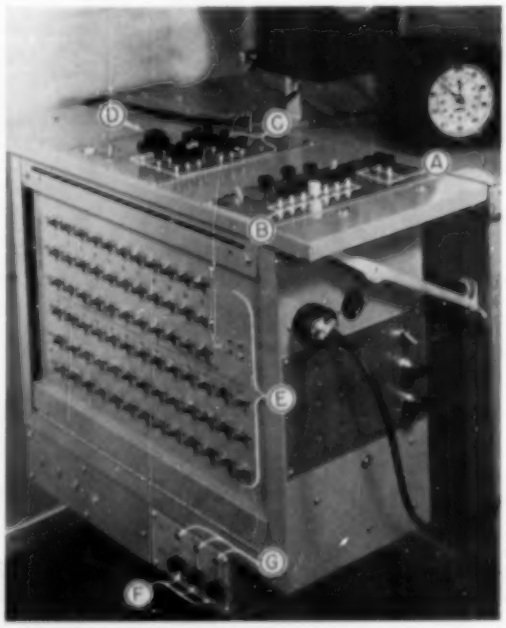

Fig. 6. Timing Control Unit—Kodak Roll Paper Color Printer, Type IVC.
A—Film-Type Buttons; B—Negative-Classification Buttons; C—Color-Correction Buttons; D—Size-Compensation Selector Switch; E—Control Button Potentiometers; F—Slope-Control Adjustment; G—Slope-Center Adjustment

* SMPTE Journal, Vol. 65, pp. 205–215, April 1956.

come a long way from the original beehive light source. There has evolved a much more versatile, a much more capable, a much more complicated, and much more expensive piece of equipment. The Model 1599 Printer in use in the Kodacolor Print program is such a piece of equipment.

Another such printer is the Kodak Roll Paper Printer, Type IVC, which is probably of more direct interest to photofinishers now embarking on negative-positive color finishing. The remainder of this discussion will relate particularly to this printer.

The Roll Paper Color Printer

The Kodak Roll Paper Color Printer, Type IVC, has been developed from the Velox Rapid Printer. Several important changes had to be made to the black-and-white printer to fulfill the additional requirements for color printing previously outlined. The controls for these printing conditions may be seen in Figure 6. The proper printing balance for different film types and illumination conditions are selected with the "Film Type" push buttons. The monitoring and timing circuit provides an automatic correction for density and color variation in the negative. The printer is also equipped with an empirical adjustment referred to as "Slope Control." Negatives that differ from standard in terms of density distribution are corrected by means of the "Negative Classification" buttons. Negatives that differ from standard because of color subject failure are rendered printable by use of the "Color Correction" buttons.

Like the black-and-white model, this is a variable-time printer. Because it is an additive printer, three exposures made through red, green, and blue printing filters, are required for each print. These exposures are controlled by two shutters operated by the monitoring and timing circuit. The schematic drawing in Figure 7 shows the monitoring system to consist of a main beam-splitter and a pair of phototubes. The main beam-splitter samples a portion of the printing beam, and the condensing-lens assembly images the projection lens upon the phototubes. A set of infrared filters must be added to the monitor beam since the Kodacolor film negative material is virtually transparent in the near-infrared region. A second beam-splitter is used to divide the light between the red-sensitive and the blue-green-sensitive phototubes. Imaging the projection lens on the phototubes improves the integration of light from the negative. The resulting phototube current is proportional to the light intensity at the paper plane. The monitor signal is fed to a timing circuit that determines the duration of the exposure. The features previously specified to provide for the printing of nonrepresentative negatives are included in this timing circuit.

The timing circuit may be reduced to its elements as shown in the schematic diagram of Figure 8. The timing unit is designed on the same principle as the Model D Timing Unit for the black-and-white printer. At the beginning of an exposure the relay 1 is pulled open leaving a negative charge on the cathode of the phototube. The phototube current, which is proportional to the exposing intensity, discharges the capacitator until

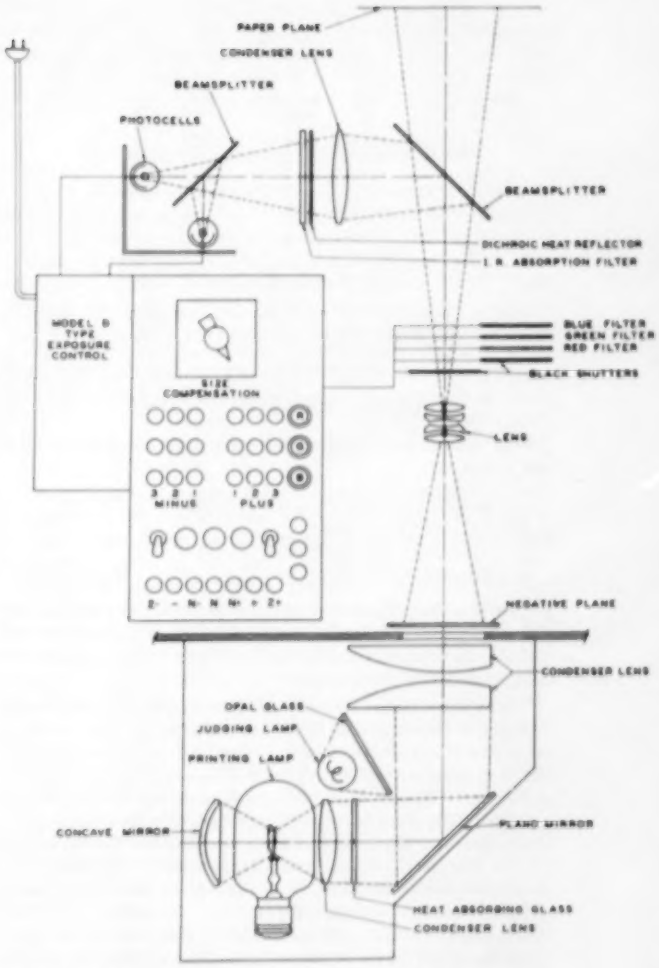

Fig. 7. Schematic Diagram: Kodak Roll Paper Color Printer, Type IVC

point A is at ground potential. The triggering Thyratron fires and the exposure is terminated. The time required to bring point A to ground potential is determined by the phototube current, which depends upon the light level, and by the potential on point A at the beginning of the exposure. Thus, the reference exposure depends upon the resistance in the voltage dividing network symbolized here by the component R_1. In actual practice the two components, R_1 and R_2, are in turn made up of many adjustable resistances; the ratio of R_1/R_2 is determined by the selection of push buttons for film type, negative classification, color correction, size compensation, and the setting of the aim-point potentiometers. This basically simple circuit with many adjustable resistances is repeated for each of the three printing exposures. The proper, exposure-time increment for each control button is adjustable by means of the potentiometer array seen at E in Figure 6.

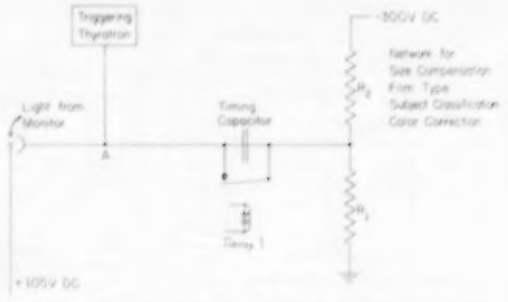

Fig. 8. Timing Circuit Schematic Diagram for Roll Paper Color Printer, Type IVC

Operation of the Printer

Four steps are required for putting the printer into operation.

1. assembly of major components,
2. optical adjustment,
3. electrical checking, and
4. photographic setup.

The Eastman Kodak Company provides several aids—the Operation Manual, the Technical Representatives, and the services of the Hawk-Eye Photofinishing Laboratory to assist in these steps.

The mechanical setup of the printer should offer little trouble. Having completed the electrical and optical tests described in the manual, the photographic setup is the last item to be considered before starting production printing. While some of the adjustments in the photographic setup may be arrived at by purely physical means, photographic tests and the inspection of the resulting prints are usual. The final adjustment of the size compensation network must be made on the basis of photographic tests, because the system includes empirical corrections for several variables. For example, there will be differences between the transmittances of the projection lenses and different spill-over of phototube illumination, with change of negative size.

As already mentioned, the monitor and timing system must correct for variations of density and color in the negative. It is further necessary that the degree of correction be the same for each of the three printing exposures. One may test the response of a monitor system by printing a set of negatives representing a latitude series, i.e., the same scene spanning the useful exposure range of the negative material. Such a test is shown in Figure 9. With different monitoring systems, rather wide variations are found in end-to-end density. For example, the cyan prints show little variation and the system is said to be well corrected, or to have a high degree of correction. The magenta series, however, has a large density variation and is said to have a low degree of correction. The graph (Figure 10) shows that there was little variation in red density with camera exposure, but indicates a large variation of green density from under- to over-exposure. This information was obtained by densitometric methods. To a trained observer, the same information may be obtained from the full tri-color printing. From such a printing it is readily seen that an exposure adjustment that would produce less exposure for the thin negatives and more exposure for the heavy negatives is required in the green-printing system. In order to produce a set of prints having the same color balance from the underexposure to the overexposure, it would be necessary to have parallel lines on the monitor response graph.

A color-printing system may be visualized with three different degrees of correction, such as is found on the plot of Figure 10. In practice such an undesirable system is really simple to construct, requiring only a different mismatch between the monitor and the photographic response for each color. When such a mismatched system is adjusted to print the normal negative, the over- and underexposures are poorly balanced as indicated in Figure 9. The ability to vary the degree of mismatch or to rotate the monitor response line about the standard negative as shown in Figure 10 is referred to as *slope control*. The optimum adjustment of the slope-control system will greatly increase the number of salable first printings. The point about which the response lines are rotated is referred to as the slope center and should be adjusted so that the majority of production prints near this point.

The criterion for slope-control performance in the photofinisher program has been tentatively stated as an end-to-end variation in color and density not exceeding the correction available with a one-button color correction or a one-button classification change. Since the slope-control system and the particular adjustment for a given printer depend upon the color paper emulsion, the paper process contrast, and the negative population, it may occasionally be necessary to readjust the slope settings on the printer.

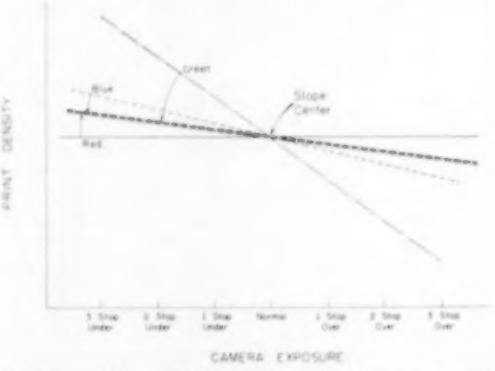

Fig. 10. Diagram of Slope Mismatch in Figure 9, with Indicated Correction

Slope Control

The slope-control adjustment is made largely by a photographic test, and a reasonable print balance for the standard negative is required. The printer is preset at the factory. A good balance is found by trial and error, which may be aided by a systematic approach. The over-all density level is determined by printing a classi-

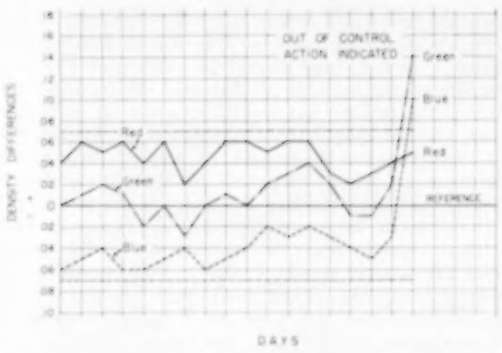

Fig. 11. Daily Chart for Printer-Process and Paper Quality Control

fication series of the normal negative and adjusting the printer so that the best print is made on the normal button. A three-button, color-correction series is printed and the best picture chosen; the printer is then adjusted to print this balance with no color correction. The process is repeated, if necessary, until satisfactory balance is obtained.

To adjust slope control, four operations are required:

1. Balance the printer for a good print from the normal negative with all slope adjustments at 50, which is mid-range.

2. Adjust the slope-center potentiometer. When no time-variation is introduced by rotation of the slope-adjustment knob, the negative will be printed on slope-center.

3. Print the latitude-series at five settings of the slope adjustment, spanning the full range.

4. Densitometer and plot the test-areas on the slope-test prints. Select the red, green, and blue curves that have matched corrections. Adjust the slope settings to these values.

A set of prints from the new slope settings should be made and visually examined. The process may be repeated, if necessary, using smaller increments until the optimum setting is obtained.

The final printer balance is now obtained for all three negative types in the manner described previously for the approximate balance. The printer is now ready to print customer negatives.

Printer Control

It is evident that considerable thought must go into the construction of an automatic color printer. In the foregoing it was pointed out that additional material and effort are required to set up the printer and put it in proper operating condition. It is only common sense to keep the printer operating in this manner.

Common tools of printer control are: the Timing Negative, the Kodak Standard Negatives, a series of Slope-Control Negatives, the Process Control Procedure, the Kodak Training Aids for Kodak Color Print Materials, Type C, and a densitometer.

Printer control normally has two separate functions: 1) to keep the printer operating repeatably; 2) to effectively change the over-all exposure level or color balance of all production. Before going on to describe these two types of control, it might be advisable to look back a bit to study the reason for control, which is to keep as much of the customer product of as good quality as possible.

Control by Photographic Methods

Since the customer product is our ultimate standard, the control man might inspect the customer pictures and steer the process by what he sees. This apparently simple method presents difficulties because, as has been seen, the negative-population varies considerably. Confronted with this wide variety in negatives, it seems logical to select a few negatives that are representative and to use prints made from these negatives as a measuring stick for production. The Kodak Standard Negatives are suitable for this purpose. Prints of these three negatives provide a quick visual check on the day's print output. They also provide a continuous day-to-day record of production.

Even a visual inspection of a group of these prints will indicate trends or changes as they occur. A highly-skilled control man could probably estimate the proper correction most of the time by inspection. However, it would be most desirable for either a skilled or unskilled operator to be able to predict the proper correction by more accurate measurement and simple calculation.

Information of the required type for such a prediction is most readily obtainable from a gray scale, which is usually exposed on a sensitometer. For convenience, however, this gray scale could be exposed on the printer. When the processed gray scale is read on the Kodak Color Densitometer, Model RT, the red, green, and blue readings may be plotted as shown in Figure 11. If one such strip were printed and read each day, comparisons of these strips would indicate the changes to be made to the printer. Determining how much change to make, will depend on the point in the scale at which the judgment is made. In an ideal system, in which all curves are absolutely parallel at all times, it would make no difference which part of the curves were used for the judgment.

Sometimes, in practical situations and with integral densitometry, curves are obtained which are non-parallel to some extent. The match might be made in the toe or light areas, or in the shoulder or dark areas. Though these mismatches may be small, it will reduce the possibility of error to balance the curves near the center of the scale. It has been found from experience that a step near a density of 1.0 serves as a satisfactory compromise balance-point.

For a quick check of the system one might pick this single step near 1.0 from the gray scale for routine control purposes. In practice, a large-area flash exposure is used to give a large and near-neutral print for both reading and visual examination. Such a print can be made by exposing the Kodak Timing Negative. Density readings from prints of this negative for all three film types may be read, plotted, and the density difference from standard noted. Using the original curve of the gray scale obtained with the Model RT densitometer, density differences may be converted into printing-time adjustments needed in the printer.

Fig. 12. Light Intensity Measurement for Printer Control

Control by Physical Measurement

Thus far, measurements have all been from a finished photographic print. Printer control may sometimes be shortened or simplified by physical measurement. Examples are the time measurement on the Type IVC Printer and the intensity measurement on variable-intensity printers. Intensity measurements are also useful on the Type IVC Printer especially for transition periods such as occur with filter changes, lamp changes, and printer setup. Such an intensity-measurement device is shown in Figure 12. When the printer is on the "Run" position and the intensity-meter probe is positioned in the paper plane, readings of intensity may be made through the red, green, and blue filters. These intensity measurements, when made with time readings, give an exact measure of the total printing flux since exposure equals intensity times duration, or time, of printing. This measure is of immediate use and need not wait on a process, as do the photographic checks. The tests just mentioned, as well as all timing checks, should be made with the printer operating with voltage regulation. Such voltage regulation of the printer is also preferred for routine operation, and is essential if voltage fluctuations on the printer-line are extreme.

Change in Aim Point

Up to this point methods and equipment have been described with the specific purpose of keeping the printer on aim. There are some times, however, when the aim of the printer might be shifted slightly. During the winter months there may be a great many indoor flash exposures resulting in rather over-exposed negatives. This effect may be compensated by slight changes of the master potentiometers on the indoor balance. Gradual changes in speed or contrast relationships also might require small adjustment in slope control. Before making any change, however small, the operator should know why he is making it.

At some point in day-to-day production, the plot of the flash-exposed neutrals may be found drifting from standard. Such a drift should be confirmed by visual inspection of the neutral patches and the standard pictures. If the process has drifted in a similar or like direction, the process control chart should be inspected to see if any errors can be located. Every effort should be made to correct any errors noted. If the process changes are small, adjustments may be made in the printer. If the changes are large, or represent a consistent drift, the whole system must be rechecked. If the process control appears on standard, the printer should be adjusted to bring the prints back into control. Under these circumstances, the Standard Negatives continue to serve as a guide, but they may not always be in the exact center of the group of negatives being printed at any particular time. Hence, minor adjustments may be necessary occasionally to keep the system operating with the highest rate of passable prints.

A Practical Example

To apply some of these principles to a practical laboratory operation, an imaginary production problem on a particularly bad day can be analyzed. Inspection of the day's run might disclose wide variations in color balance and density level. First, the unsatisfactory prints should be separated and sorted into separate groups according to type of defect. As shown in *Figure 13* they fall into five categories: 1) obvious subject failures, 2) blue balance, 3) dense prints, 4) cyan balance, and 5) red balance.

The first group contains four prints. They are classic examples of color-subject failure. The only method of handling these pictures, if better prints are desired, is to reprint with color correction.

The second group of prints shows that a sizable fraction of the day's production has a blue balance. Most of these blue prints are from negatives with outdoor exposures. Checking the control charts and pictures indicates that the outdoor-exposure printer balance is blue. Densitometry indicates the need for an increase in the blue printing time. If these pictures are reprinted with the required time change in the outdoor balance, the results should be much improved.

The last two groups of prints from the unsatisfactory production are of two distinct balances, one red and the other cyan, but appear also to be related in another respect. Closer examination indicates all the red pictures are from underexposed negatives, and all the cyan pictures are from overexposed negatives. From the description of the slope-control unit, it is sound to suspect that a change in slope could help these pictures. This is the case. A change is needed to the red adjustment of the slope-control unit. A series of increases in the red slope might be attempted. The corrected prints of each of the five categories are shown in Figure 14.

The several examples given here were chosen to illustrate how a routine color printing problem can be isolated, analyzed and solved as it occurs. Careful and accurate day-to-day control procedures should reduce the production loss from such problems to a minimum.

PACKAGED CHEMICALS FOR COLOR PROCESSES

Donald J. Kridel*

SUMMARY

The exacting quality requirements of processing solutions for color work are discussed. Described are special packaging techniques and the extensive testing carried out to assure the uniformity so necessary for good color processing.

In processing black and white films and papers, considerable freedom can be exercised in the choice of processing solutions. The processor may also vary his conditions of times, temperature, and agitation over relatively wide limits to obtain the particular effect desired.

The processing of color products, however, is much more restrictive. In general, for a given color film or print material, there is a specific set of solutions to be used to obtain optimum results. Further, since the results can only be judged after the completion of the processing sequence, the operator must rely on the manufacturer's recommendations regarding time, temperature, and type of agitation. Although some process variations may be practiced by one completely familiar with the color process, in general, the keynote for successful color processing is compliance with recommended procedures and standardization of each element of the process which includes sensitized goods, processing solutions, and processing equipment and procedures.

It is desirable, first of all, that the sensitized goods be of uniform quality. The manufacturer has primary responsibility for quality but the manufacturer's instructions with respect to storage and care of the film should, of course, be followed.

Equally important is uniformity of quality of the color processing solutions.

The color processor may wish to prepare his own solutions from basic chemicals, or he may elect to buy packaged photographic chemicals. Should he decide to compound his own formulas, to obtain satisfactory results he must provide a staff of technically trained personnel with testing facilities adequate for this job.

The Use of Packaged Chemicals

However, in the field of black and white processing the use of packaged chemicals has gained almost universal acceptance. This has been due to the ability of manufacturers to supply economical products uniform in quality and conveniently packaged. Most black and white operators have found that, economically, the preparation of their own solutions from bulk chemicals cannot be justified. It may be expected, therefore, that most color processors will rely upon the use of packaged chemicals.

The prime objective of Kodak packaged chemicals for color work and black and white as well is that, properly used, they give results uniformly equivalent to the "standard process" maintained in Kodak laboratories. This standard process, specified in terms of chemical makeup of the solutions and time, temperature and method of agitation employed in the processing sequence, is historically the one agreed upon or developed when the specific film or print material was worked out. It serves as the primary reference in quality evaluation of the sensitized goods and chemicals produced for the process. These standard processes are maintained by having available adequate technical personnel and, to insure that process specifications are being met, facilities for analysis of raw materials and processing solutions, and for the necessary sensitometry.

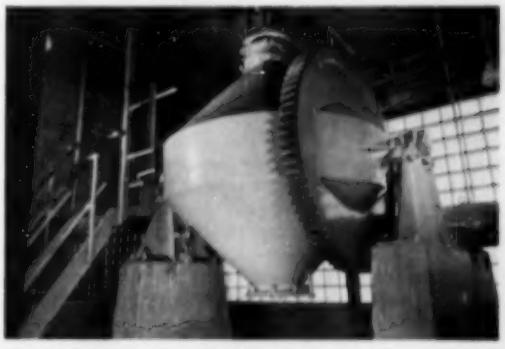

Fig. 1. Double cone blender for preparing processing chemical mixes up to 6,000 pounds in weight.

It is expected, for example, that each and every unit of Ektachrome E-2 First Developer may be dissolved by anyone, anywhere, and produce results matching the standard process. Further requirements of packaged chemicals include stability in packaged form, ease of solution, freedom from sludges and insolubles, and lowest possible cost compatible with the other objectives.

The first step in building quality and uniformity into packaged chemicals is control of raw materials.

The raw materials produced by the Eastman Kodak Company for their own use or purchased from outside suppliers are covered by rigid chemical and physical specifications developed over a number of years. Stocks are transported and warehoused in a way to prevent contamination, moisture pickup, or carbon dioxide absorption which would deteriorate the quality of the material.

Representative samples from each batch are checked for conformance with specifications, including maximum limits of impurities to insure proper photographic action

* Photochemicals Division, Eastman Kodak Company, Rochester 4, New York. Presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York 26 May 1956. Received 27 September 1956.

and good solution quality. In addition, certain of the more critical items, for example, the color developing agents, are tested photographically for their specific use in color work.

To achieve lowest possible cost, most chemical mixes are blended in batches weighing up to 6,000 pounds. (Figure 1) Conventional double-cone blenders without interior baffles are employed. Because they can be cleaned rather easily, this type is advantageous where a number of different chemical mixtures are to be made. Each batch is blended a minimum of twenty minutes to insure uniformity of mixing.

For larger quantities of material, continuous mixing equipment is available. Although giving high productive capacity, it is used most efficiently where substantial runs on a given mixture are required. In this continuous system, as many as eight components may be proportioned continuously, feeding each component onto a constant speed belt which is part of a scale beam system. Figure 2 shows the proportioning devices. The chemicals are charged into the suspended hoppers from the floor above and are fed onto the constant speed belt by means of vibrating conveyors. The oscillations of the scale beam are fed back to electronic controllers, shown on the left of Figure 3, which control the amplitude of vibration of the feed conveyors. In Figure 3 is also shown the handling of 2,000 pound containers of bulk chemicals. The proportioned ingredients of the mixture are then blended in a rotary blending device shown in Figure 4.

The mixtures after passing the required chemical or photographic tests, are weighed into the unit package. Weighing is done on automatic high speed equipment designed to give the accuracy required by the formulas. The accuracy of the unit weight is monitored by check-weighing devices which pass to the capping machine only units within preset weight limits.

The recently introduced color processes, however, presented mixing problems beyond the scope of our usual techniques. For example, in the 3-1/2 gallon Ektachrome E-2 First Developer, the amount of potassium iodide required by the formula is only 2 grains with a manufacturing tolerance of ± 2 percent. The amount in the First Developer of the pint Ektachrome E-2 Kit is only .07 grains. It appears to be hopeless to achieve the required degree of uniformity by the usual mixing and packing techniques.

The Ektachrome E-2 First Developer also contains sodium thiocyanate in the formula. This material is generally damp and sticky, about like brown sugar, and is almost impossible to blend uniformly. A further problem in the Ektachrome E-2 First Developer is that the organic antifoggant, 6-nitrobenzimidazole nitrate, is slowly soluble and the user could experience difficulty if insufficient agitation were employed. These three difficulties were overcome by providing as a component of the E-2 First Developer a liquid auxiliary which contains accurately controlled amounts of these three ingredients and the required potassium bromide content.

These solutions may be made in large batches, precisely analyzed and dispensed to the individual bottles using automatic equipment with a precision of a few tenths percent.

Control of Critical Items

The Ektachrome E-2 Color Developer, which also contains small amounts of critical components, poses similar problems. In addition, there exists the problem of pH control. The manufacturing tolerance for pH is ± .06 pH units. These limits are actually just about equal to the reproducibility that can be achieved by a good operator having good, carefully adjusted equipment. To accomplish this exacting control, the technique of supplying the critical components as a liquid auxiliary is again employed. This auxiliary solution contains the bromide, iodide, benzyl alcohol, and ethylenediamine sulfate—and, in addition, the exact amount of caustic soda to produce the required pH in the working solution.

Fig. 3. Charging 2,000-pound containers of chemicals into the feed hoppers. The electronic controllers on the wall at the left govern the oscillation of vibrating conveyors which meter the chemicals going into the rotary mixer shown in Fig. 4

Fig. 2. Proportioning devices for feeding separate ingredients into a continuous mixer for dry chemical preparations.

Those familiar with the product will recall that the package directions specify rinsing the bottle provided with the Color Developer with tank solution. It is obvious that if the customer fails to do this, he will upset much of the precision which has been built into the product.

Each batch of color chemicals is subjected to careful chemical analysis prior to packaging and chemical and

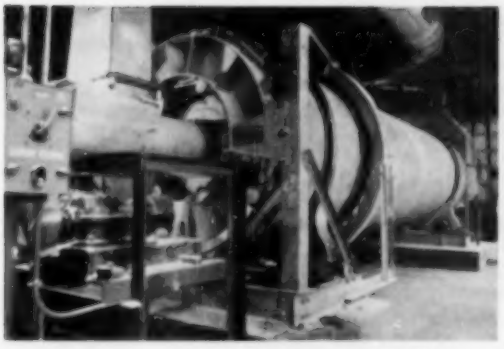

Fig. 4. A conventional rotary type blender

physical release tests are also made on finished product samples.

In the case of First Developers and Color Developers, in addition to chemical analysis, color sensitometric tests are made on each batch of component parts and samples of finished product are also so tested and not released unless these tests are passed.

The use of these packaged chemicals, plus the use of the control strip systems, will give the essentials of a dependable process.

The Kodak Process Control Kits, available for Kodak Ektachrome Film, Process E-2, and for Kodacolor Film, Process C-22, describe in detail the operation of this system and also give specimen strips showing the results of some conceivable processing errors, their diagnosis, and cure.

Packaged chemicals are designed to make the job simple and easy. By carefully following dissolving directions, anyone should be able to obtain solutions which, if used according to process specifications, will give results of high quality. Even the average worker in the amateur field can produce highly satisfactory results.

The examples previously discussed were taken from the Ektachrome E-2 Process in which there has now been approximately two years commercial experience. The same techniques of chemical control, formulation, and testing of the packaged chemicals are being employed in production of components for the Kodacolor Negative C-22 Process and for the Color Print Processes P-111 and P-122 for the Type R and Type C paper, and for Replenishers for these systems.

SAFE HANDLING OF PHOTOGRAPHIC PROCESSING CHEMICALS

D. W. Fassett, M.D.*

SUMMARY

The safe handling of industrial chemicals in the processing laboratory requires proper control of volatile materials, of caustic or corrosive liquids, and of harmful dusts in the bulk handling of solids. The problems and means of control of skin allergy or skin sensitization to chemicals apt to be encountered in the processing laboratory are discussed in detail.

THERE IS NOTHING very peculiar or extremely difficult about the safe handling of photographic processing chemicals. The principles involved are identical with those for the safe handling of any industrial chemical.

The development of color photography has, of course, resulted in the introduction of new types of photographic chemicals. While many of these are widely used in the chemical industries, some of them may not have been familiar to people who are engaged in black-and-white photographic processing.

Training of Employees

The most important factor in the safe handling of chemicals is the proper training of all supervisors and employees. This should be done both by discussion and demonstration and, if possible, by some written instructions. Training should be a continuous matter, not to be done once and then lost sight of.

It is of importance to read all warning labels on containers and to read and study all statements in the processing instructions which deal with matters of safe handling. A general reference book which would seem to be very useful for processing laboratories is "Safety in the Chemical Laboratory" published by the Manufacturing Chemists Association, Van Nostrand, 1954.

Design of the Laboratory

Laboratories where photographic processing is carried out should be designed so that all surfaces which are apt to be contaminated can easily be flushed down with water, adequate provision being made for floor drains. The need for considering adequate ventila-

* Laboratory of Industrial Medicine, Eastman Kodak Company, Rochester 4, New York. Presented at the Color Processing Conference, sponsored by the Technical Division of the P.S.A. in Rochester, New York, 25 May 1956. Received 4 September 1956.

tion to take care of various volatile materials should be emphasized. This includes both general, and in some cases specific local ventilation.

Provision should be made, where concentrated chemicals are being handled, for safety showers and for washing out the eye in case of an injury. Facilities should be made available for washing the hands in all areas where chemicals are being handled and not merely in locker or washrooms. Locker rooms with showers should be available.

Storage of Chemicals

Some types of color processing involve the use of flammable chemicals, and, of course, these must be stored according to the regulations of insurance companies and of the state. Self-closing safety containers should be used for flammable and hazardous materials. No smoking should be allowed in areas where volatile solvents are stored or used. Adequate ventilation should be provided for the storage area. It is of importance to keep bottles of strong caustics, acids, etc., stored on low shelves in order to avoid possible breakage and spillage on the face or upper part of the worker's body.

Weighing and Dispensing

Most accidental skin or eye burns occur during some phase of the weighing or dispensing of liquids and solids. If the process is on a large scale, the use of a weighing hood is recommended. All spilled dust should be sucked up with a vacuum rather than by sweeping. Employees who are engaged in weighing or dispensing chemicals should be provided with jackets which are laundered frequently, dust respirators if the need arises, rubber gloves, and safety goggles. Many accidents occur during the handling of glass bottles and carboys. These can be avoided by the use of tilting cradles and by the use of the Benson carrier for handling glass bottles.

If possible, all dispensing of larger amounts of solvents and liquids should be done by metering pumps rather than by hand. It is hardly necessary to mention the great hazard of pipetting any chemical by mouth. Acids should always be added to water and not vice versa because of the heat evolved. All spills of acids and caustics should be washed down promptly.

Storage Tanks

Storage or replenisher tanks should be located in well lighted areas. Tanks should be covered, if possible. Sometimes floating covers are useful. Good ventilation of storage tank areas is of obvious importance since volatile materials may be present. Local exhaust ventilation of large tanks containing volatile materials may be necessary. Leaky pumps or connections must be repaired promptly.

Processing Room

Important items in the processing rooms are:

1. Provision of good general ventilation. These machines should not be placed in small or crowded rooms since the ventilation will then be difficult. In addition to good general ventilation (for example twenty air changes per hour is not unreasonable) it may be necessary in some cases to use local exhaust ventilation for tanks containing formalin or aliphatic amines.
2. Facilities for washing the hands with an acid type hand cleaner should be available. (See comments on removal of chemicals from skin.)

Maintenance and Cleaning of Equipment

It is of importance that all maintenance people be trained to avoid skin contact with chemicals or contaminated surfaces. This is often lost sight of. A program of scrupulous housekeeping is needed in all areas where chemicals are handled and frequent inspections should be made to be certain that cleaning has been adequate.

Personal Protective Equipment

All employees who routinely handle chemicals should be provided with gloves and someone should be assigned a specific responsibility for cleaning, repairing and maintaining gloves A neoprene glove such as Davol #2382 is generally useful. Gloves should be put on and taken off so that the inside is not contaminated by the solutions. After each use the gloves, before removal from the hands, should be thoroughly and promptly washed with an acid hand cleaner and water in order to reduce the tendency for absorption of chemicals into rubber. Safety goggles should be provided and should be worn at all times when handling caustics or strong acids. If dust respirators are used they should be kept clean, and filters changed as specified by the manufacturer. A one minute scrub of the rubber face pieces with pHisohex, followed by a water rinse is an effective and simple cleaning procedure. Frequent laundering of work clothing is desirable and shower facilities should be provided.

Emergency Treatment of Skin or Eye Burns

In the event of contact of hazardous liquids, solvents or solids with the skin or eyes *immediate* flushing of the area with copious amounts of water should take place. In the case of the eye, the lids should be held open (some help may be needed from a fellow worker) and the eye washed with a gentle stream of running water for at least ten minutes. Clothing or shoes contaminated with acids, caustics, etc., should be immediately removed and the underlying area flushed with large amounts of water for ten minutes. All employees must know the location of safety showers and eye baths and the proper methods of emergency treatments of chemical burns. Medical attentions should be had for all skin and eye burns.

The word dermatitis simply means inflammation of the skin due to any cause. However, it is frequently used in talking about the type of inflammation which may result from a skin allergy. The latter is also referred to as a contact dermatitis or skin sensitization.

There are, of course, many types of skin inflammation which do not result from an allergic reaction. Acids, caustics, oxidizing agents, etc., may damage the skin by direct chemical action. This is also true of other agents such as solvents, excessive ultraviolet rays or x-rays, heat or cold or even mechanical abrasion. All of these agents, however, act essentially alike in all individuals and their

action does not depend on the development of any allergy or special sensitivity of the individual's skin.

In contrast with the materials just mentioned, there are some substances which may be handled with apparent impunity for weeks or months and then suddenly cause skin inflammation in some persons from even a slight contact. This is because the skin has developed an altered reaction as a result of repeated previous contacts with a particular chemical, with the result that wherever the chemical touches the skin some swelling or redness or itching may develop.

Some color developers have an effect of this type and the same is true to a lesser degree of black-and-white developers. Formaldehyde and dichromate salts used in some color processing solutions may also be the cause of the difficulty. This allergic skin reaction is not limited to color processing chemicals and is occasionally found with various other types of industrial chemicals.

Skin allergy also occurs from contacts with natural products such as poison ivy. The familiar symptoms of hay fever result from a somewhat similar process in which case pollen or dust may cause a sensitivity of the membranes of the eye or nose.

The time taken for the sensitivity to develop may vary anywhere from two or three weeks to perhaps several years or more. The degree of sensitivity in people also varies. Once the sensitivity has developed it may last for a long time although occasional individuals appear to undergo a reduction in degree of sensitivity. The sensitivity may be quite specific and limited to a given chemical. Physicians sometimes test for this by placing a small amount of it under controlled conditions on the skin. It is impossible, however, to predict in advance of exposure whether a person will become sensitive.

Factors Which Predispose to Dermatitis

Among the more important factors which predispose to skin allergy are frequency and extent of skin contacts, exposure to more highly concentrated solutions and the duration of individual contacts. Previous injuries to the skin such as those caused by exposure to alkaline solutions, detergents, solvents, chapping and cuts or abrasion may allow chemicals to penetrate more quickly. Excessive sweating may predispose to difficulty especially in the handling of dry solids. Persons who have a long history of skin allergies to many chemicals or childhood eczema etc., are probably more apt to get into difficulty although this does not occur invariably. There seems to be little difference in ability of different races or sexes or between blondes and brunettes in ability to develop skin allergy.

Prevention of Dermatitis

1. Education of employees. This is of great importance as in the case of all matters dealing with the safe handling of chemicals. Supervisors, plant physicians and nurses must be quite familiar with the necessary protective measures. They must be made a routine part of the job and carried out 100% of the time.

2. Prevention of contact with chemicals. This involves cleanliness of working areas, the use of rubber gloves whenever possible, particularly in mix rooms or in cleaning tanks or in maintenance work. It is important to teach employees how to take care of gloves and to wash the gloves after each use with an acid hand cleaner. A long study by this laboratory of many types of protective hand creams has shown them to be relatively ineffective against contact with potent skin sensitizers of the color developer type.

3. Removal of chemicals from the skin. Next to complete prevention of exposures, one of the most important single measures that can be taken to reduce likelihood of dermatitis is to remove sensitizing chemicals promptly from the skin. This can be done by the prompt use of an acid type hand cleaner after each known contact with chemicals, particularly with color developers.

Some examples of acid type hand cleaners which have been found satisfactory are pHisoderm or pHisohex (Winthrop-Stearns), pH 6 (Stepan Chemical Company), or Sulfo Hand Cleaner (West Disinfecting Company). Others of this type would probably be useful. Within minutes after contact with these chemicals, particularly color developers, the hands should be thoroughly washed with the acid hand cleaner and with water. This should be repeated after each known contact or several times a day even if no known contact occurs. Therefore, these acid hand cleaners should be available in all areas where these chemicals are handled such as mix rooms, laboratory and processing rooms.

4. Proper procedures in case of development of dermatitis. It is important in such an instance that an employee notify his supervision immediately if he thinks he has developed any difficulty with his skin. He should be seen by a plant physician or nurse as soon as possible. If emergency treatment to relieve severe itching or burning is needed before a physician can be seen, the safest thing to do is to compress the affected area with clean towels moistened with cool dilute table salt solution (a teaspoon of salt in a pint of water). No one should attempt to treat himself with ointments, lotions, etc., for this condition, as this may aggravate the difficulty. If the difficulty is treated promptly most employees can return to their work in processing unless they are unusually sensitive. This should only be done, however, after consultation with a physician.

Summary

Some of the safe principles for handling of industrial chemicals which apply to photographic processing and in particular to color processing have been outlined above. Experience has shown that the precautions suggested are necessary and it is also known that a strict observance of them can eliminate nearly all employee loss of time from this cause.

SOME EFFECTS OF EMULSION pH AND pAg ON RECIPROCITY FAILURE AND LATENT IMAGE FADING

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ABSTRACT

The effects of emulsion coating pH and pAg on the formation and stability of the latent image have been investigated. Experiments were carried out on the effects of these variables on low intensity reciprocity failure, high intensity reciprocity failure and latent image fading. The pH was varied from 5.3 to 7.4 and the pAg from 8.7 to 10.5 in factorial experiments using bromo-iodide emulsions at two levels of chemical sensitization.

The sensitivity of both the surface and internal latent image at low exposure intensities increased with increasing pH and decreasing pAg as well as at medium intensities as has been demonstrated previously. The sensitivity at high exposure intensity was similarly affected. Low intensity reciprocity failure of the surface latent image and latent image fading decreased with increasing pH and decreasing pAg. Low intensity reciprocity failure of the internal latent image and high intensity reciprocity failure were not affected by emulsion pH or pAg.

A statistical analysis of the experimental results showed the effects of pH and pAg on sensitivity to be interdependent at medium and low exposure intensities. At high exposure intensity the effect of the interaction of pH and pAg on sensitivity was not significant. The effect of the interdependence of pH and pAg on low intensity reciprocity failure was not significant.

THE TYPICAL photographic emulsion is an aqueous silver halide system in which two reversible chemical factors predominate: (1) the silver ion concentration and (2) the hydrogen ion concentration. These factors in turn influence the chemical and physical behavior of the grain, the binder and the dyes or other additives which may be present. However, the effects of emulsion pH and pAg on reciprocity phenomena have not received sufficient attention, in part due to the omission of sufficient emulsion information in many papers in this field. The results of some recent experiments on these effects are offered to increase our understanding in this important area.

Experimental Techniques

The emulsions used were laboratory-prepared from an ammonia ripened bromo-iodide (1.7 mole % iodide) precipitation using lime-processed bone gelatin. Chemical sensitization was used without optical sensitizing dyes or antifogging adjuvants. The coating weight of silver halide on cellulose acetate film base was 1 mg./cm.^{2} ± 2% and except for pH and pAg all emulsions in a set were identical. The pH and pAg values refer to the measured quantities in the liquid emulsions prior to coating. No attempt has been made to relate these values with probable values of pH and pAg in the coated emulsion layer. Emulsion pH was adjusted with either sulfuric acid or sodium hydroxide and measured with an electrometer using a glass electrode and a saturated calomel reference electrode. The pAg was adjusted with calculated quantities of potassium bromide and checked using a silver electrode.

Exposures for the various experiments reported here were made on laboratory sensitometers using step wedges. Exposures from 0.04 to 4000 seconds were made using tungsten illumination through a Wratten 47-B (blue) filter. The log E values of the tungsten exposures were regulated by the use of Wratten neutral density filters.

A reproducible high intensity exposure of about 10 microseconds was made with an Edgerton Mark III discharge tube sensitometer. The intensity of this exposure was arbitrarily controlled by a Wratten neutral density filter to give a total exposure of the same order of magnitude as the medium and low intensity exposures. Exact control of Log E was not attempted in this case, but the results and conclusions of the high intensity reciprocity failure experiment were not affected by this approximation.

A Metol-hydroquinone developer of the following composition was used with constant agitation at 20 C. for 5 minutes:

3.0	grams Metol
9.0	grams Hydroquinone
50.0	grams Na_2SO_3
50.0	grams K_2CO_3
4.5	grams KBr
	Water to make 1 liter

Diffuse visual densities were measured on laboratory densitometers. The shapes of the characteristic curves of the emulsions used in this study were essentially identical and fog values were low and very nearly the same. Relative speeds and speed differences have been recorded in an arbitrary scale representing displacement along the Log E axis at a density 0.10 above fog. A difference of 1.0 on this scale equals 0.30 Log E or very nearly a factor of two in exposure and the higher the speed number the greater the sensitivity (1).

Experimental Results

Two separate sets of emulsions were made in which pH was varied from 5.3 to 7.4 and pAg from 8.7 to 10.5

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Table I

RELATIVE SPEEDS—LOW INTENSITY RECIPROCITY FAILURE EMULSION SET #1

		pH 5.3	6.0	6.7	7.4	Relative Exposure Intensity
pAg	8.7	5.4	5.7	5.5	6.1	1
		3.8	4.2	4.3	5.4	10^{-2}
	9.3	4.5	4.8	5.6	5.8	1
		2.7	3.0	4.2	4.6	10^{-2}
	9.9	4.7	5.5	5.5	5.8	1
		2.5	3.7	3.8	4.4	10^{-2}
	10.5	3.6	5.0	5.4	5.6	1
		1.5	2.8	3.7	3.8	10^{-2}

in a 4 × 4 factorial design (4). Low intensity reciprocity failure, high intensity reciprocity failure, and latent image fading were examined.

A. *Low Intensity Reciprocity Failure*

1. *The Effect of Exposure Intensity.* Speeds for 1 second and 1000 second exposures of equal Log E values are recorded in Table I for the 16 emulsions of one of the two sets of emulsions used. Sensitivity increases with increasing pH and decreasing pAg. This is a well known effect and need occupy no further attention here.

Differences in speeds at the two exposure intensities (i.e. relative low intensity reciprocity failure) are recorded in Table II. These differences increase with increasing pAg and with decreasing pH.

2. *Effect of Chemical Sensitization.* The second set of emulsions was prepared similarly to the first except that a 5°F. lower digestion temperature was used. The same trends were demonstrated with pH and pAg except that low intensity reciprocity failure was more pronounced. Decrease of low intensity reciprocity failure with increasing chemical sensitization is well known (2). These data are recorded in Table III and IV. The data of Tables I and III were used in the statistical calculations to be described later.

3. *The Effect on Internal Latent Image.* Emulsion pH and pAg might be expected to influence surface concentrations of hydrogen or hydroxyl and silver or bromide ions. It was thus expected that the effects of emulsion pH and pAg would be associated primarily with the surface latent image. This was tested by investigating low intensity reciprocity failure of the internal image of emulsions selected from those already described.

The experimental technique has been described in detail elsewhere (3). A Metol-isoascorbic acid developer and ferricyanide bleach were used. The first of these experiments tested 4 of the 16 emulsions in the first set (Table 1) across the diagonal from pH = 5.3 and pAg = 10.5 to pH = 7.4 and pAg = 8.7. The results are listed in Table Va, but because of the very small amount of internal image it was necessary to estimate speeds at very low densities. The two extremes of this diagonal were tested a second time and the results are recorded in Table Vb.

The results of these experiments are in satisfactory agreement. Although internal sensitivity at both normal and low intensities is affected by emulsion pH and pAg, relative differences in low intensity reciprocity failure apparently are not. The effects of emulsion pH and pAg on low intensity reciprocity failure appear to be associated with the surface latent image.

Table II

RELATIVE SPEED DIFFERENCES—LOW INTENSITY RECIPROCITY FAILURE EMULSION SET #1

		pH 5.3	6.0	6.7	7.4
pAg	8.7	1.6	1.5	1.2	0.7
	9.3	1.8	1.8	1.4	1.2
	9.9	2.2	1.8	1.7	1.4
	10.5	2.6	2.2	1.7	1.8

Table III

RELATIVE SPEEDS—LOW INTENSITY RECIPROCITY FAILURE EMULSION SET #2

		pH 5.3	6.0	6.7	7.4	Relative Exposure Intensity
pAg	8.7	3.9	4.4	4.7	4.7	1
		1.9	2.7	3.0	3.3	10^{-2}
	9.3	3.6	3.7	3.8	3.8	1
		1.1	2.1	2.3	2.8	10^{-2}
	9.9	3.1	3.9	4.1	4.2	1
		0.5	1.7	2.0	2.1	10^{-2}
	10.5	2.5	3.6	3.9	4.1	1
		0.0	1.5	1.7	2.0	10^{-2}

Table IV

RELATIVE SPEED DIFFERENCES—LOW INTENSITY RECIPROCITY FAILURE EMULSION SET #2

		pH 5.3	6.0	6.7	7.4
pAg	8.7	2.0	1.7	1.7	1.4
	9.3	2.5	1.6	1.5	1.0
	9.9	2.6	2.2	2.1	2.1
	10.5	2.5	2.1	2.2	2.1

Table Va

LOW INTENSITY RECIPROCITY FAILURE OF INTERNAL LATENT IMAGE—FIRST TEST

Emulsion pH	7.4	6.7	6.0	5.3
Emulsion pAg	8.7	9.3	9.9	10.5
Δ Speed*	2.5	2.0	2.5	2.5

* Speed differences estimated at densities less than 0.10 above fog.

Table Vb

LOW INTENSITY RECIPROCITY FAILURE OF INTERNAL LATENT IMAGE—SECOND TEST

Emulsion pH	7.4	5.3
Emulsion pAg	8.7	10.5
Normal Intensity Speed	4.2	3.0
Low Intensity Speed	1.5	0.5
Δ Speed*	2.7	2.5

* Speeds determined at densities 0.10 above fog.

4. *Statistical Significance of the Data.* To determine reliability the data from the low intensity reciprocity failure experiments were subjected to an analysis of variance (4). The data were in the form of speed values at a series of levels of emulsion pH (4 levels), emulsion pAg (4 levels), chemical sensitization (2 levels), and light intensity (2 levels). The 64 data used for the

Table VI

RESULTS OF THE ANALYSIS OF VARIANCE OF LOW INTENSITY RECIPROCITY FAILURE

Factors	Significance at 1% Level of Confidence
Exposure Intensity	Significant
Chemical Sensitization	Significant
Coating pH	Significant
Coating pAg	Significant
Two Factor Interactions	
Intensity × Sensitization	Significant
Intensity × pH	Significant
Intensity × pAg	Significant
pH × pAg	Significant
pH × Sensitization	Not Significant
pAg × Sensitization	Not Significant
Three Factor Interactions	
pAg × pH × Sensitization	Not Significant
pAg × Sensitization × Intensity	Not Significant
pAg × pH × Intensity	Not Significant
pH × Sensitization × Intensity	Not Significant

analysis were not duplicated and it was necessary to assume that the 4 factor interaction of pH × pAg × sensitization × intensity was not significant and that its contribution was included in the original residual variance. Since the residual standard deviation was no greater than the precision to which the original speed values were given (0.1), this assumption appeared justified. Table VI lists these factors, their interactions and their significance at the 1% level of confidence.

The results of this analysis can be of value in interpretation in addition to being a check on the reliability of these data. The significance of the three two-factor interactions involving exposure intensity confirmed that pH, pAg and chemical sensitization all influence low intensity reciprocity failure as well as sensitivity. Over the range of variables tested here chemical sensitization had the largest effect.

The significance of the two-factor interaction of pH and pAg indicates that the effect of either pH or pAg on speed depends to some extent on the level of the other. However, it should be noted that the three factor interaction of pH, pAg and intensity was not significant. This latter result suggests that the interdependent effect of pH and pAg on speed is not involved in low intensity reciprocity failure to the extent measurable here.

The two-factor interactions of pH or pAg and chemical sensitization are not significant and the same is true of the three-factor interaction of these variables. The three-factor interaction of pH or pAg with chemical sensitization and exposure intensity was not significant in these data.

5. *Discussion of Low Intensity Reciprocity Failure Results.* The failure of the reciprocity law at low intensities has been ascribed to the degradation of the latent image, or particularly the latent sub-image, during formation. Explanations include the "thermal" degradation hypothesis of Lüppo-Cramer (5) based on the strong temperature dependence of the phenomenon. More recently this idea has been discussed by Webb, Katz and also by Mecklyar (6). It has been pointed out that a chemical degradation would be similarly temperature

Table VII

RELATIVE SPEEDS—HIGH INTENSITY RECIPROCITY FAILURE

		pH 5.3	pH 6.0	pH 6.7	pH 7.4	Approximate Relative Exposure Intensity
pAg	8.7	3.9	4.0	4.0	4.1	1
		2.9	3.4	3.2	3.1	10^4
	9.3	3.2	3.5	4.1	3.9	1
		2.7	2.8	3.2	3.3	10^4
	9.9	3.0	3.4	3.6	3.8	1
		2.5	2.8	2.6	2.8	10^4
	10.5	2.2	3.2	3.4	3.4	1
		1.9	2.6	2.6	2.2	10^4

sensitive (7). In this regard the activation energy for low intensity reciprocity failure of 17 Kcal./mole as measured by Webb (6) may be more typical of the activation energy of a chemical reaction than of a thermal trap. The dependence of low intensity reciprocity failure on the chemical factors pH and pAg as demonstrated in these experiments support a chemical reaction point of view.

Chemical attack on the latent image or sub-image by residual bromine has been hypothesized by Berg (8). The bromine-water equilibrium can be expressed in part by:

$$Br_2 + H_2O = 2H^+ + OBr^- + Br^-$$

and low pH and high pAg would both favor the existence of free bromine which might attack the latent image. Our data tend to agree with this view, but this specific equation implies an interaction of pH and pAg on low intensity reciprocity failure which is not supported by the statistical analysis of the data from these experiments. Other equilibria may be involved, of course. Atomic bromine plays a role in the stability of the latent image in recent views by Evans, Hedges and Mitchell (9) and by Mitchell (11).

Recent hypotheses by Loening, Sutherns and Bourne (10) suggest an internal "crystalline" image and a surface "complex" image formed by silver ions and various anions, including hydroxyl ions. The surface complex image exhibited strong low intensity reciprocity failure in liquid emulsion systems. Our data on the effect of pH and pAg on low intensity reciprocity failure in coated emulsions were shown to be associated primarily with the surface image and agree with such a view. Mitchell (11) has also suggested a stabilizing role for silver ions in promoting the aggregation of latent sub-images to latent images.

The internal sensitivity is dependent on pH and pAg although the degree of low intensity reciprocity failure of the internal image is not. This result suggests that the efficiency of processes associated with the formation of an internal image depends on surface conditions even if the subsequent stability of such an image does not.

6. *The Chemical Behavior of Certain Antifoggants in Relation to Low Intensity Reciprocity Failure.* Certain classes of antifoggants increase low intensity reciprocity failure. A specific example is the well known compound 5-methyl-7-hydroxy-2,3,4-triazaindolizine which Birr has shown too chemically complex with silver ion (12). This chemical behavior would reduce the effective silver ion concentration on or near the silver halide grain.

Table VIII

SPEED DIFFERENCES—HIGH INTENSITY RECIPROCITY FAILURE

		pH			
		5.3	6.0	6.7	7.4
pAg	8.7	1.0	0.6	0.8	1.0
	9.3	0.5	0.7	0.9	0.6
	9.9	0.5	0.6	1.0	1.0
	10.5	0.3	0.6	0.8	1.2

A worsening of low intensity reciprocity failure under these conditions is compatible with our data at high emulsion pAg.

B. *High Intensity Reciprocity Failure*

The effect of emulsion pH and pAg on high intensity reciprocity failure was studied by comparing relative speeds at exposures of 0.04 second and about 10 microseconds of approximately equal total exposure. Only one set of emulsions was studied since chemical sensitization has relatively little effect on this phenomenon (2).

1. *The Effect of Emulsion pH and pAg.* Results are recorded in terms of speeds at 0.04 second and 10 microseconds (high intensity) exposures in Table VII. The relative speed differences are given in Table VIII.

These data show no clear effect of pH and pAg on high intensity reciprocity failure. However, pH and pAg did influence speed at both high and low intensities in a manner described previously for low intensity reciprocity failure. The residual error in the experiment was larger (0.2) perhaps due to variations in the discharge tube sensitometer.

2. *The Statistical Significance of the Data.* The high intensity reciprocity failure data were analyzed by the variance method. However, since this experiment was carried out on only one set of emulsions at one level of chemical sensitization and without duplication, it was necessary to assume that the three-factor interaction of pH, pAg and intensity was not significant. Table IX lists the factors, their interactions and their significance.

The effect of pH and pAg on speed was found to be significant at the 1% level of confidence. However, the effect of the interactions of pH and pAg with the light intensity were both found not to be significant, indicating that pH and pAg apparently did not affect high intensity reciprocity failure. The effect of the interaction of pH with pAg on speed was also found not to be significant in contrast to the results obtained in the low intensity reciprocity failure experiment. It is possible that the effects of all these interactions in the high intensity reciprocity failure experiments were small enough to be masked by the residual error.

3. *Discussion of Results.* Gurney and Mott (13) considered that high intensity reciprocity failure was due to the limited mobility of silver ions compared to that of electrons. The activation energy of high intensity reciprocity failure as measured by Webb (14) agrees well with the activation energy of interstitial silver ion mobility from experiments of Lehfelt (15) which lends support to this point of view. Lüppo-Cramer (16) suggested that high intensity latent images were internal and subsequent experiments by Berg, Marriage and Stevens (17) and Debot (18) support this hypothesis.

Table IX

RESULTS OF THE ANALYSIS OF VARIANCE OF HIGH INTENSITY RECIPROCITY FAILURE

Factors	Significance at 1% Level of Confidence
Exposure Intensity	Significant
Coating pAg	Significant
Coating pH	Significant
Interactions	
pH × pAg	Not Significant
pH × Intensity	Not Significant
pAg × Intensity	Not Significant

Our data showed that sensitivity at high intensities was influenced by pH and pAg in the same manner as at normal intensities. This is similar to the sensitivity of the internal image at low intensities discussed in the preceding section. This suggests that high intensity images tend to be internal, but our experiments did not specifically investigate this point. Our data showed no effect of surface pH and pAg on high intensity reciprocity failure and this might be expected whether or not the phenomenon is governed by internal latent image or internal interstitial silver ion migration.

C. *Latent Image Fading.*

1. *The Effect of Emulsion pH and pAg.* The fading of the latent image was studied by aging exposed samples at room temperature and humidity which averaged about 74°F. and 65% R.H. in a continually air-conditioned laboratory. The data presented in Table X represent an average of two readings of the same set of emulsions after 13 and 14 days aging. Fading was measured by comparing the density before and after aging at an exposure step providing approximately half the maximum density. The percentage drop in the density after aging represented the change in the number of grains still developable and was considered a desirable way of recording this phenomenon.

Fading of the latent image increased with increasing pAg and decreasing pH, i.e., the stability of the latent image was favored by an increase in silver ion concentration and hydroxyl ion concentration.

The effects of pAg and pH on latent image fading were found to be statistically significant by methods previously described, but the experiments were insufficient to determine the significance of the interaction of pH and pAg on latent image fading. The effect of emulsion pH and pAg on latent image fading was strikingly similar to the effect of pH and pAg on low intensity reciprocity failure.

Table X

AVERAGE % LATENT IMAGE FADING IN 13½ DAYS

		pH			
		5.3	6.0	6.7	7.4
pAg	8.7	21	15	5	10
	9.3	54	48	19	13
	9.9	80	67	55	29
	10.5	67	79	75	49

2. *Discussion of Results.* The fading of the latent image following exposure has been considered related to low intensity reciprocity failure by Loening (19) and our data agree with this view. In binderless silver halide sols low pH and high pAg accelerate latent image fading according to Loening, Sutherns and Bourne (10). Albouy and Faraggi (20) showed that latent image stability increased with pH in 3 commercial emulsions, but considered the increasing grain size in these 3 emulsions an additional factor.

Moisture also has a pronounced effect on latent image fading. The fading observed by Loening (10) in a liquid sol was relatively rapid even under favorable conditions. Several workers (19) have noted the increase in fading with increasing humidity in coated emulsions (21). It seems that the mechanism is the same in both liquid and coated systems and is favored by the presence of water.

The chemical effect of oxygen on fading seems to depend on humidity, but there is some disagreement on this point (22). Since our data were obtained with emulsions stored only in air, these considerations are beyond the scope of this paper.

Conclusions

The concentrations of silver ions and hydroxyl ions in photographic emulsion influence the formation of the latent image (the sensitivity) and its stability (low intensity reciprocity failure and fading). Sensitivity of the internal latent image at medium and at low intensities is dependent on pH and pAg, but low intensity reciprocity failure of the internal latent image is not. Therefore, the dependence of low intensity reciprocity failure on pH and pAg is associated with the surface latent image.

High intensity reciprocity failure is not affected by pH and pAg, although sensitivity at high intensity is affected.

A statistical analysis of the data indicated the effect of pH and pAg on sensitivity to be interdependent. However, the data did not show the interdependent effect of pH and pAg on low intensity reciprocity failure to be significant. This may suggest that the mechanisms of formation and degradation of the latent image are different in detail although both chemical in nature.

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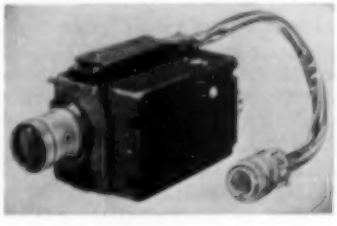
DATA-RECORDING CAMERAS

Data-recording cameras previously available only for military purposes are now released for general industrial and commercial use.

Flight Research, Inc., of Richmond, Virginia announces the availability of their "SynCameras" for single-frame or continuous motion sequence pictures. The 16mm film model uses 50 ft. magazines and the 35mm film model accepts magazines loaded with any length from 100 ft. to 1,000 ft.

An exclusive feature is the synchronous control system, contained within each camera. The electrical interlock permits two or more cameras located any distance apart to be used simultaneously with the shutter and film drives synchronized to an accuracy of one and one-half milliseconds. Three individual coding lights in each camera permit the identification of film sequences and record time signals on the film.



Industrial uses of multiple cameras in synchronization include time-and-motion studies, the analysis of mechanical movements, testing techniques, studies of processes and equipment performance. They may be particularly useful in cause and effect studies where the cause is at one station perhaps miles away from the effect.

FUNDAMENTALS OF REVERSAL COLOR PROCESSING

D. B. Glass and J. A. Cogan*

ABSTRACT

The two basic types of reversal film, incorporated-coupler and coupler-developer, are discussed. The processing requirements for making color transparencies are outlined and related to the important features of the structures of the two films. The reasons for the requirement of more complex processing equipment and control techniques for the coupler-development system are explained and correlated with the added possibilities of process control afforded by this system.

Reversal color films are in general made up of three layers of silver halide emulsion, each of which has been sensitized to a different portion of the visible spectrum. The blue-sensitive layer is on top, the green-sensitive layer is in the middle, and the red-sensitive layer is on the bottom. In addition to these layers, there is a yellow filter layer and various gelatin interlayers. Figure 1 diagrams the cross section of a reversal film. The top layer, which is blue-sensitive, is developed to a yellow image, the middle or green-sensitive layer is developed to a magenta image, and the bottom or red-sensitive layer is developed to a cyan image. These dye images are formed during development by the reaction of the coupler with the oxidized color developing agent. These reactions will be discussed later.

There are two types of reversal color films. In one, the incorporated coupler type, the couplers are incorporated in the film during the manufacturing process. Ektachrome and Anscochrome films belong to this class. In the second type, the couplers are not in the film but are dissolved in the processing solutions. These couplers react with the oxidized developer and the resulting dye is deposited in the film. Film of this type is really made up of three superimposed black-and-white emulsions, which are sensitized to the red, green, and blue portions of the visible spectrum. Kodachrome film belongs to this second class.

In reversal development the following are the essential steps:

1. First development
2. Re-exposure
3. Color development
4. Bleach
5. Fix

In addition to these fundamental steps, the different processes require various other treatments during processing that are characteristic of the films themselves. For example, Ektachrome film requires a hardener after the first development to harden the emulsion so that it will retain its shape during the remainder of the process and also be in a hardened condition after processing. The process used with Kodachrome film requires the hardener before the first development. In addition, the different processes include washes that vary as to time and place. Other baths are used during processing for special purposes; an example is the stabilizing bath used with Ektachrome film.

* Eastman Kodak Company, Color Technology Division, Rochester 4, New York. Presented at the Color Processing Conference sponsored by the Technical Division of the PSA in Rochester, New York, 25 May 1956. Received 27 August 1956.

Each one of the basic processing solutions contains several ingredients essential to the type of operation being carried out at this point in the process.

First Developer

The ingredients of the first developer are essentially those of any good black-and-white developing solution. These include such black-and-white developing agents as hydroquinone and Elon, or combinations of these two. Also present are: a restraining agent such as bromide, an alkali to maintain the pH at a proper level, usually some type of antifoggant, and, of course, sulfite. Other ingredients present perform a useful function in the development of the specific type of film for which they are used.

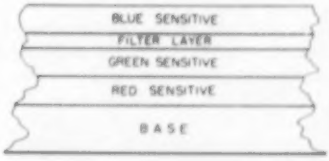


Fig. 1. Cross-sectional diagram showing layer construction of a typical reversal film for color photography.

Color Developers

The color developer or developers, in general, are made up of restrainers, sulfite, antifoggants, alkali and a color developing agent. The latter is one of the key components in producing dye in the film. For Kodachrome film the color developing solutions also contain a water-soluble coupler. Use of a water-soluble coupler makes it quite apparent that it will be necessary to develop the cyan, yellow, and magenta images in three different color developing solutions. The film after first development is exposed in the cyan (red light) printer and then is developed in a cyan developer. This produces the cyan image in the red-sensitive layer. Next the film is exposed in the yellow (blue light) printer and the yellow color developer produces yellow dye in the blue-sensitive layer. Following this the magenta dye is developed in the green-sensitive layer. The color developers used to produce the three dyes in Kodachrome film are basically the same in that they contain the usual alkali, antifoggants, restrainers, and sulfite, and differ mostly in the fact that three different couplers are used to produce the cyan, magenta, and yellow dyes. The color developers for Anscochrome, Ektachrome, and similar films in which the coupler is

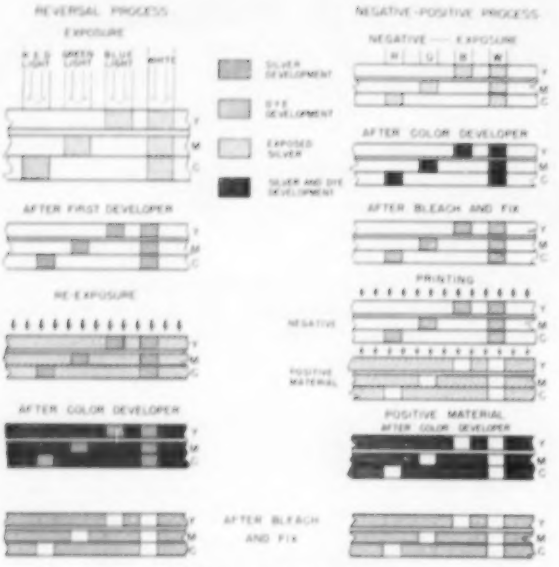


Fig. 2. Graphical comparison of the reversal process for color photography, left, with the color negative—color positive process, right.

incorporated in the emulsion, are composed of a color developing agent, which is usually a phenylenediamine derivative, plus the usual sulfite, alkali, restraining agents, and antifoggants. In some processes either a developing agent or a coupler giving a water-soluble dye is used to control the amount of dye formed for a given exposure.

In the first developer, the exposed silver halide reacts with the developing agent to produce silver and oxidized developer. At this stage of the process only silver development is desired, and the oxidized developer produced is an undesirable by-product which is destroyed by reaction with the sulfite. In the color developers the silver halide exposed in the re-exposure step reacts with the color developing agent to produce silver and oxidized developer. At this stage of the process the oxidized color developer is a desirable product, producing the required dye in the film by reacting with the coupler present in the film or solution.

$$\begin{aligned} AgX &+ Dev. \longrightarrow Ag + Ox\ Dev. \\ Ox\ Dev. &+ Coupler \longrightarrow Dye \end{aligned}$$

It might be interesting to consider the differences and similarities between reversal films and films used in the negative-positive system as shown in Figure 2. With negative films, such as Kodacolor, the film is exposed and then processed in a color developer in which the dye image is formed along with a silver image. The film is then treated with a bleach and fix to remove the silver and residual silver halide and a negative image in color results. To obtain a positive image from this negative, an exposure is made through the negative onto a color paper or film and the same development cycle is repeated.

In the reversal system, the film is exposed and then developed in two stages. In the first stage the film is developed in a black-and-white developer to give a negative silver image. This image is strictly a negative image and, theoretically at least, could be used as such. If a color developer were used for the first development instead of a black-and-white developer, a negative image in color would result along with the negative image in silver. In processing reversal films, instead of fixing out the film after the first developer, as is done in the negative-positive system, the residual silver halide in the film is reexposed and then it is developed in a color developer, or in the case of Kodachrome, color developers. After this color development, the film contains a positive image in color and both a negative and positive image in silver. The silver and residual silver halide are removed by bleaching and fixing so that a positive image in color is obtained. The essential difference between the two systems is apparent. In the negative-positive system two separate materials are used for the negative and positive parts of the system. In the reversal system only one material is involved, and development proceeds through a negative stage to the positive end product.

Fig. 3. Typical arrangement for processing color films of the Incorporated-Coupler type in a sink by manual methods.

Essentially the photographic mechanism for both the incorporated-coupler film process and coupler-developer system is the same; that is, silver development, reversal color development, then removal of the residual silver and silver halides. However, the methods of color formation differ considerably from the standpoint of processing and film manufacturing. A large portion of the burden for the successful balancing of factors that will produce the desired photographic result rests with the emulsion manufacturer in the case of the incorporated-coupler product (henceforth called IC type). However, for the coupler-developer product (henceforth called CD type) more of this responsibility rests with the processor.

Table I

COMPARISON OF BASIC PROCESS STEPS

IC Type	CD Type
First Development	Prehardener (to soften antihalation backing and harden film)
Hardening and Stop Bath	First Development
Re-exposure	First Re-exposure
Color Development	First Color Development
Clearing Bath	Color Auxiliary Development
Bleach (to convert silver to halide)	Second Re-exposure
Wash	Second Color Development
Fix (to dissolve silver halides)	Second Color Auxiliary Development
Wash	Third Re-exposure
Stabilizing Bath	Third Color Development
Drying	Bleach
	Fix
	Wash
	Dry

Many different film types and sizes are manufactured for both systems. For the sake of simplicity, an analysis of the process machinery and control techniques will be considered for a 35mm, 20-exposure, reversal color film strip.

Incorporated-Coupler Films

Processing Machines

IC films have been available for several years for processing by the amateur with simple processing accessories used for the home darkroom. Commercial processing of Ektachrome and Ansochrome films has been accomplished in a number of ways, varying from sink processes to continuous machine processes. The primary machine requirements are a film conveying device and a series of processing vessels. Figure 3 illustrates a typical arrangement for operation in a sink. Small reels in reel holders are immersed in $3^1/_2$-gallon tanks and transferred by hand from tank to tank. Machines become more complex when the output and the degree and type of control increase. A more elaborate machine, shown in Figure 4, contains larger processing vessels and has a more convenient method of film suspension and a mechanical transporting device.

The characteristics of IC film processing machines are particularly interesting when one considers the needed controls. These fundamental controls can be listed in three categories: Mechanical Control, Chemical Control, and Photographic Control.

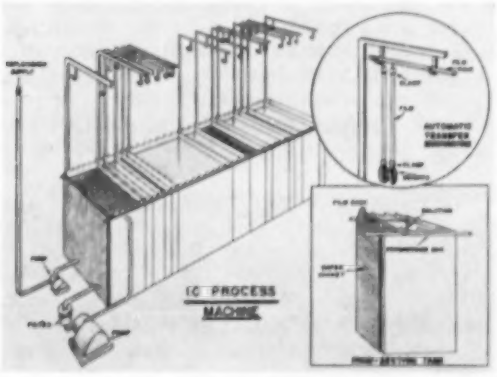


Fig. 4. Schematic arrangement for processing machine for larger scale manipulation of Incorporated-Coupler type color films.

Mechanical Control

Several mechanical control items that must be considered when the processing equipment is built are: Temperature, agitation, time, flow rates, re-exposure, and removal of antihalation layers. All of these have an influence on the photographic result.

1. *Temperature.* The temperatures of most solutions are satisfactory if controlled within ±2°. However, $\pm^1/_2°$ control is required in the first developer. For the most part this temperature control can be conveniently accomplished by a tempering bath, and the temperatures can be measured with an alcohol thermometer.

2. *Agitation.* Agitation is not too critical in comparison with that required for some color products. Hand agitating systems are satisfactory but give less reproducible results than agitation obtained through a mechanized technique.

3. *Time.* Control of processing time is very similar to that required in most black-and-white processes with the exception of the first developer in which time must be controlled within ±15 seconds. This task can be performed effectively with hand timing devices or could be done by means of a systematic scheduling device. Such devices signal an alarm to permit the processor to move specified racks from one solution to the next.

4. *Flow Rate.* Flow-rate control could be considered in two parts; that concerned with supplying fresh chemicals to the processing solution and that concerned with the efficiency of washing between the processing steps. Of foremost importance is the rate of chemical addition to the processing solutions since the replenisher solutions control the rate of the chemical reactions. However, most of the important phase of the photographic reaction is accomplished in two operations, first development and color development, and in these solutions the rate of addition is important. A sufficiently satisfactory chemical balance can usually be maintained in the developers by adding fresh replenisher solutions at given intervals. In the case of the remaining solutions the chemical concentrations are at a sufficiently high level to permit completion of the chemical reactions. Small variations in concentrations of these solutions do not affect the results significantly. With reference to the rate of washing, a resonable rate of a gallon and one-half per minute for each of the wash solutions will produce satisfactory results.

5. *Re-exposure.* Re-exposure may or may not be required for an IC process. When required, this exposure is generally of "white light" type, and it is only necessary to insure that sufficient re-exposure is provided.

6. *Antihalation Protection.* In some film types the method of removing antihalation backing may be an item of concern. Antihalation protection in IC films is generally provided by silver dispersions that are removed in the bleach and hypo solutions. No additional mechanical action is required to assist in the removal operation.

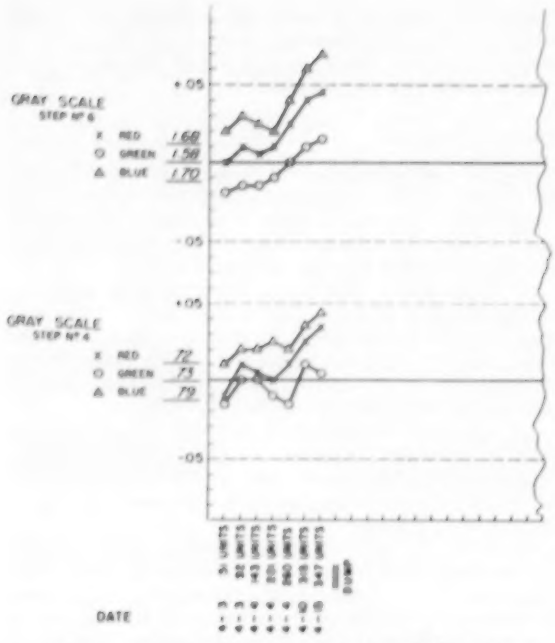


Fig. 5. Control chart for plotting integral densities of Incorporated-Coupler type color film to maintain uniformity of processing.

Chemical Mixing

Mixing of the processing solutions is the most involved chemical operation in the IC system. For each of the solutions, kits of chemicals are provided which are carefully prepared by the photographic vendors. In addition, detailed descriptive information is included outlining the proper mixing procedures for each solution. Mixing equipment for this type of process is not elaborate. The chemicals are relatively stable and effect a homogeneous mix after a brief stirring period. Mixing of the first developer and color developers requires care to prevent aerial oxidation with resultant deterioration of these chemical solutions. If the vendors' recommendations are followed, satisfactory process mixes are generally obtained.

Chemical Control

Chemical control for the IC system is even less involved. If the processing kits are properly prepared according to the manufacturers' recommendations, little additional chemical trouble is to be expected. It has been found from experience that the IC system operates smoothly without further chemical monitoring. Fortunately only two solutions, the first developer and color developer, present significant chemical control problems. The film manufacturer offers realistic procedures that permit the processor to use the chemical solutions to exhaustion and then to dump these solutions, or an alternative replenishment method of adding fresh chemicals to the machine tanks at regular intervals. With the replenishment method, calibrated metering vessels or other suitable flow-rate equipment can be used to regulate the introduction of the replenisher chemicals. Accurate metering of additions to the first and color developers is essential for successful control of the IC process. With either the replenishment or tank exhaustion method, the processing solutions are discarded after a given period of time and fresh solutions introduced. Careful records of the age and degree of exhaustion of solutions are important to determine when the solutions should be discarded. If this principle is followed, further checking of the chemical concentrations in the processing solutions is not essential. Experience has shown that the practice of dumping solutions at regular intervals has the additional advantage of removing the accumulated dirt and film particles which may form during the continuous process operation.

One shortcoming of the IC system is that process control troubles are not corrected chemically. When process troubles occur, the processing solutions are discarded and fresh processing solutions are put into the production line. Generally, the loss is not too great since it is necessary to dump only two solutions, the first developer and the color developer, in which most of the photographic difficulty occurs. To know when trouble occurs, a photographic control system is needed to measure the quality of the process.

Photographic Control

Routine process monitoring is by sensitometric control strips. These strips are packaged by the photographic vendors, together with the photographic standard, in much the same manner that packaged chemicals are provided for the process. Properly refrigerated storage of these photographic control strips is important to prevent excessive change of the latent image before use. If storage effects do occur, errors in the control information will result.

Because the processing steps are straightforward, there are few chances for making mistakes and infrequent process checking is required. It is necessary to examine the process strip visually or with a color densitometer and to record the photographic results on a control chart (Figure 5). The control chart is used to record the process quality rather than to provide diagnostic information for corrective action, because the processor is not concerned with process adjustments to alter the mechanical or chemical conditions. When corrective action is indicated from the control strips, either minor mechanical adjustments are made or the processing solutions are dumped.

Coupler-Developer Films

Process Machines

Process machines for the CD system consists of, again, a film conveying device and processing tanks. Not only are additional tanks required, as compared with the IC system but additional control accessories are required to assure successful operation. Figure 6 shows a typical machine installation for this process.

Mechanical Control

Additional mechanical control features needed for this processing equipment include: Systems for tempera-

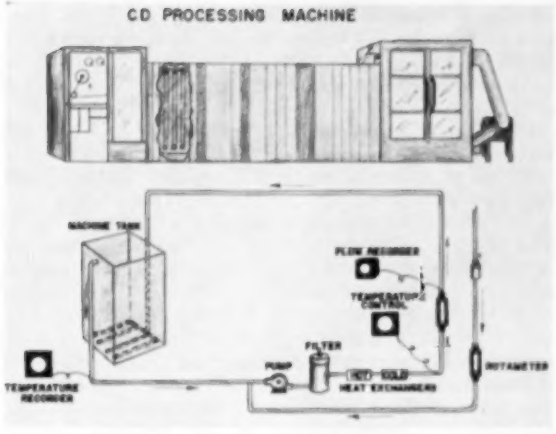


Fig. 6. Schematic arrangement of continuous processing machine for use with Coupler-Developer type films, showing necessary controls.

ture control, filtration, flow control, and agitation. In many cases the controls are similar to those of the IC system but with these exceptions:

1. Temperature. The temperature of each solution must be controlled to within $\pm 1/4°$. For this purpose heat interchangers and automatic recording devices are usually installed to regulate and record the temperatures of the processing solutions.

2. *Process Times.* The processing solution times are controlled more closely. Limits of ±15 seconds are typical for each of the six processing solutions, that is, the first developer, the three color developers, and the two auxiliary developers. These requirements suggest a machine designed for continuous operation in which the speed or time control can be governed quite accurately.

3. *Agitation.* Variations in the rate of agitation of the developers have a significant effect on the photographic results. Agitation of the processing solution is often provided by recirculating distributors, which are positioned to force the chemical solutions against the film surfaces. Additional agitation is frequently obtained as the speed of travel of film through the processing machine is increased. Machines in which the film follows a helical path adapt very well to this type of process.

4. Replenisher Rates. Replenisher flow to the six critical solutions should be metered accurately as small variations in the developer concentrations will affect the photographic results. Accurately calibrated rotameters or metering pumps are desirable for regulation of these replenisher rates.

5. Wash Rates. The rate of flow, time of immersion, and temperature of the washes between the various processing solutions also require maintenance within the control specifications. Greater care must be exercised to prevent the chemical contamination of these washes than is required in the IC process.

6. Re-exposure. Either two or three printers are required in the re-exposure set-up for the Kodachrome film system. The intensity and quality of light of these printers are important if reproducible photographic results are expected.

7. Antihalation Removal. The antihalation backing on Kodachrome film requires a chemical and physical treatment for removal prior to the first development. The prehardener chemically softens the backing, and a mechanical scrubbing device in the wash following the prehardener buffs away this material from the film.

8. Solution Filtration. Filtration is recommended for each of the chemical solutions because the developing solutions contain some constituents that tend to precipitate from the solutions. If these precipitates are allowed to remain in the processing machine, stains and chemical dirt will be left on the film strips. Filtration also serves to remove dirt and extraneous materials originating during the processing cycle.

9. *Closed Recirculation System—Start-Up–Shut-Down.* Agitation, temperature control, replenishment, and filtration are most conveniently combined in a closed system. These closed system processors, when operated with these additional chemical control features and with an involved processing sequence, do not permit a rapid start-up and shut-down because each of the mechanical variables must be adjusted correctly before satisfactory processing control can be obtained. To accomplish this task successfully, an orderly system of mechanical control is desirable which will assist the process operator to determine whether the various mechanical components are operating within the process specifications.

Chemical Mixing

In the CD system, kits are not ordinarily provided for the process because problems of chemical stability and packaging make kit preparation impractical. Therefore, bulk chemical mixing is needed. Any impurities in these chemicals may have an important effect on the photographic reactions that occur during processing. For this reason it is important that the chemicals be procured from reputable vendors who have been supplied with realistic chemical specifications for the chemical agents. Typical chemicals found in the developer formulas include water softeners, antifoamants, antiprecipitates, developer preservatives, developing agents, buffers, antifoggants, restrainers, caustics, processing couplers, competing couplers, and antistain agents. Each of these ingredients is used for a specific purpose in executing or controlling the photographic reaction.

Once these chemicals have been accepted under these specifications and assigned to a suitable storage space, the chemical mixing can proceed. The mixing requirements are more exacting because of the involved chemical formulation. On-center agitation or up-draft agitation is frequently recommended to prevent severe vortexing of the solutions and subsequent excessive oxidation of the chemical constituents. Transfer and sampling of the finished mixes are equally important, as sloppy techniques at this stage can result in further chemical problems. Once the mix is prepared, a preliminary analysis is recommended to see if the chemicals are at the proper concentrations. It is not uncommon to adjust the mix composition slightly at this stage to bring it within the control specification. After the mix has been adjusted and rechecked, the solution is either transferred to a storage tank or fed directly to the processing tank. To accomplish this job a rather large mix installation is

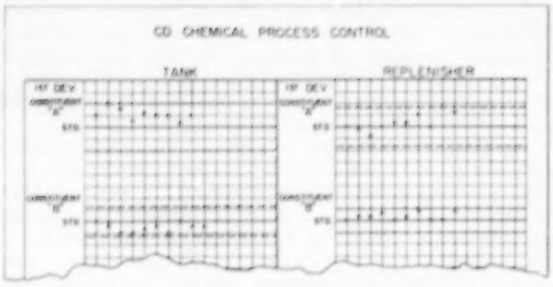


Fig. 7. Chemical process control check chart for use with Coupler-Developer type color film processing.

required to provide facilities for the six developing solutions in addition to the prehardener, bleach and hypo solutions.

Chemical Control

Unfortunately, in the CD system the chemical problems do not end with proper mixing of the tank and replenisher solutions. Even with the assurance that the basic chemicals and mixes meet specifications, it is also necessary to check the chemical compositions of the solutions in the processing tanks during the production run. These routine checks do not consist of single chemical measurements for each processing solution, but consists of several measurements. Results of the chemical analyses are usually recorded on a chemical control chart to provide the process operator with a running record of the solution concentrations throughout the process run (Figure 7).

Maintenance of this control chart involves plotting the information on both the tank and replenisher solutions. This information must then be translated by the process operator so that suitable corrective action can be taken if required. Chemical programing of this type would be straightforward if all the significant chemical variables that affect the photographic results could be measured. At present our knowledge is incomplete. Sometimes it is difficult to determine exactly when and what to adjust chemically. However, with proper technical analysis of chemical and mechanical data, most control problems can be solved. With chemical control, when properly handled, the processor has an opportunity to adjust color balance, speed, and contrast of the process. This opportunity for such adjustments is much more limited in the IC process.

Photographic Control

Again a photographic reference strip is used to measure the characteristics of the processing result. For the CD process a slightly different photographic control system is needed. Packaged sensitometric control exposures are not available in this system. If these exposures were to be prepared by the photographic vendor, the processor might find them unsuitable as a measuring stick for the photographic control. Slight changes in film manufacture, non-uniformity of exposure, and variation in film keeping are just a few of the problems in obtaining reproducible control strips. Since the control tool in the CD system will be used to adjust the photographic level of processing, it must contain more accurate information about the photographic conditions of the process than is required in the IC system. Specially prepared sensitometric exposures made at the processing laboratory are used for this purpose. This function necessitates another laboratory operation to provide and control the sensitometric reference strips. A film stock must be selected for use as a process monitor. The possible sources of variability of this film must be determined so that a representative sample is obtained for control purposes. Careful storage of the control films is required to prevent keeping effects. Sensitometric exposures should be made with a precisely controlled sensitometer. Variations encountered in the control stock, control stock storage, or sensitometric exposures will be reflected in the precision of the photographic measurements of the process. Simply expressed, the problem involves measuring variables with variables. Because this is true, it is important that each of the variables be controlled as closely as possible to make the measurements as meaningful as possible.

In the case of the CD system, the photographic checking device is used to provide diagnostic data to predict changes required for the process. Variations of density of speed, contrast, color balance, and maximum density are all factors which must be considered before corrective action should be taken. With the aid of a photographic control chart, as shown in Figure 8, decisions can be made as to the need for or desirability of changes to be made in the process.

Summary of Control Features

IC Type

A single photographic control center is needed to measure the quality of the IC process. If the mixing has been properly done, and if the chemical kits have been properly packaged, reasonable photographic results are expected. Chemical control is not a necessity for satisfactory quality in the IC system since much of this control is built into the system with packaged kits. It is also true that the processor is not offered a means of regulating the photographic results of the process. Although some speed modification is possible, such modifications must be performed with caution to avoid curve shape distortions. Simply expressed, the film has built into it most of the features required for good contrast, speed, and color balance control. Processing in this case is just a means for obtaining the required photographic results rather than for regulation of the result.

CD Type

In the case of the CD system the processing program is more complex. It is difficult to get the system rolling; once started it is difficult to shut the system down without upsetting the balance. Many mechanical and chemical variables must be checked and compared with the photographic results before it is reasonable to consider processing production film. This involved programing

of the CD system suggests the convenience of a continuously operated system.

A chemical laboratory is desirable to check the initial mixes and the tank solutions as well as to provide interpretation of the process chemistry on a routine basis. An additional sensitometric control laboratory is desirable to produce the sensitometric exposures and to analyze the quality of the processed results. Chemical and mechanical control is important, and close adherence to the process specifications is the key to optimum results. Altogether a process nerve center is assembled that consists of three major units—mechanical, chemical, and photographic control. With the proper functioning of these units, the processor has a means for controlling the process. However, a coordinated effort must be made to obtain reproducible results.

Commercial Application

1. Scale of Operation

Several commercial considerations will influence a decision for either of the two process systems. One is versatility. The IC system lends itself to either small-, intermediate-, or large-scale production volumes. Small-scale production volumes are often handled using a sink, $3^1/_2$-gallon or smaller rubber tanks, and processing reels. These small-scale installations will serve quite readily for production volumes below 50 rolls per hour. Larger-scale operation could be considered for 50 to 300 rolls per hour. In this case larger-scale processing equipment such as the Kodak Rack and Tank Processor, Model 10E, would be more desirable than sink operation. Also rack-and-tank processors of the type used for roll film adapt quite readily to this production volume. In this case the equipment is more mechanized to assure greater output and to obtain better process reproducibility at lower labor costs. Even larger-scale systems could be considered for the incorporated coupler type above 300 rolls per hour output. Process machinery for this type of installation would entail even greater automation and could be done in either rack-and-tank or helical path continuous machines.

With the CD system, because of the higher initial installation cost, small scale or even intermediate-scale processing does not have the competitive advantage of a larger-scale system. Rather expensive facilities are required, such as chemical analysis, sensitometric control, and a closed system for the process machine. As the volume approaches 500 rolls per hour, the continuous helical path machines offer production advantages over other types of processing machinery. However, installations have been prepared in the intermediate-scale classification, but for the most part the equipment and facilities are similar to that used for the large-scale installation.

2. Installation Cost

It is difficult to compare capital investments for these two systems since many different types of machine designs could be considered. The cost of the material, fabrication, and installation will vary depending on the location. For systems of comparable size for handling about 500 rolls per hour, an initial investment for the CD system would be anywhere from one and one-half to two times the cost of the IC system. This higher cost arises from the increased complexity of the facilities

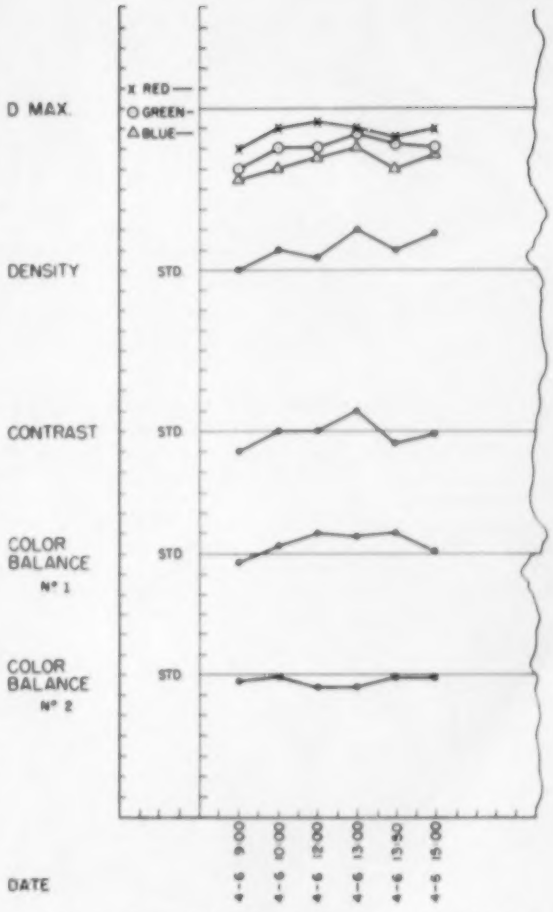


Fig. 8. Control chart for plotting integral densities of Coupler-Developer type color film to maintain uniformity of processing.

required, and the need for a photographic control center, a sensitometer, densitometer, and a completely equipped analytical laboratory.

3. Personnel

Operational cost also varies for the two systems. A laboratory with a potential production of 500 rolls per hour requires considerable technical and professional help to perform the operations of the CD process satisfactorily. Included in the personnel would be trained chemists for chemical certification and analytical control work, a photographic engineer to supervise the over-all activity beginning in the chemical mix stage and through the finished processing stage, and a quality control engineer to correlate and analyze the sensitometric and photographic data, from both mechanical and chemical viewpoints, to keep the process in proper adjustment. Some additional process labor would also be required. From an operational standpoint the cost would be somewhat higher than that associated with the IC system for these same services. It is entirely

possible that one quality engineer at an IC laboratory, with the needed processing labor, could operate a process at a 500 roll-per-hour rate.

4. Operational Skills Required

The degree of experience and skill required in these two systems also varies. A modest amount of skill is required to handle the IC system, whereas the team must be well-coordinated in the case of the CD system to perform its functions with a high degree of precision. Many things can go wrong during the sequence of operations in a CD process. Process problems must be handled by qualified personnel who are capable of making the right decisions.

Much of this burden is taken out of the IC system because most of the control features are built into the film and process kit, with the result that there is less opportunity for processing trouble. Fewer decisions are needed for corrective action, hence fewer variables are in the hands of the processor for control purposes. Equipment, techniques and procedures are made simpler, making the processors' task easier.

5. Maintenance

The maintenance of these two systems differs slightly, as the additional equipment of the CD system requires frequent servicing to assure proper functioning. It is conceivable that a shop would be desirable to offer the needed repair facilities for the CD system.

6. Chemical Costs

Chemical costs are often misjudged by the processor as a potential source of considerable saving. It is generally believed that buying chemicals in bulk is more economical than buying packaged chemicals. For certain cases of large production, this is true. It must be remembered, however, that properly prepared mixes are made only after a great deal of equipment and talent has been invested in the mixing and analytical operations. In some cases the additional cost of packaged chemicals may be no greater than the cost of mixing from bulk, when additional checking operations are considered for the bulk chemicals.

Conclusions

The outstanding features of the two reversal systems can be summarized as follows. The incorporated-coupler system has versatility for output on a varying scale with low initial investment, lower operating cost, and limited demand for control regulation. In the CD system the advantages are fewer. They depend mainly upon the possibility of process control, which can be an outstanding asset in obtaining good process repeatability, when a highly integrated technical control system is used. There is no conceivable reason why the quality of one product system should be superior to that of the other. One of the larger factors influencing a decision as to the desirability of the two products is the process variability encountered. Good quality and reproducibility, both from a processing standpoint, are outstanding features of the Kodachrome film system. The incorporated-coupler system can offer good quality whether processed in small or large quantities. Fundamentally the two reversal processes are similar in that at first negative silver images are formed which are converted later in the process to dye images. The reversal processes differ mainly in the method and number of steps which are used to form the dyes.

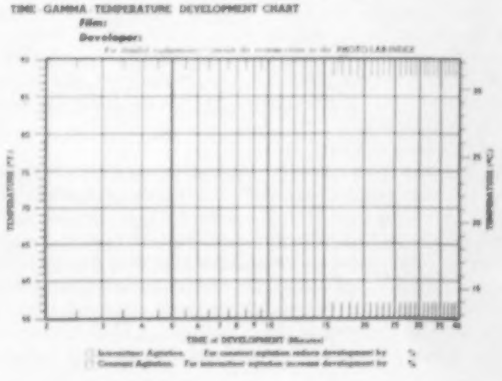
UNDERWATER PHOTOGRAPHY OF ATOMIC FUELS

Water-filled concrete pools in an atomic reactor building provide an underwater "studio" for the photography of fissionable fuel elements at the Hanford atomic plant in the sagebrush country of eastern Washington State, according to the General Electric News Bureau.

John M. Fouts, of the General Electric organization which operates Hanford, stated that work performed there under the shield of water may prove of great value in the development of practical fuel pieces for atomic power reactors. The water, 11 to 17 feet deep, absorbs the radiation from the "hot" uranium rods, protecting the research personnel as they use novel underwater equipment to clean them, weigh them, determine their radioactivity, dimensions, grain size, and photograph them.

At the photographic station, each uranium piece is placed on automatically operated rollers, under 11 feet of water. A modified aerial telephoto camera is suspended over the pool. A long glass-bottom air-tight cylinder mounted vertically and dipped into the pool permits the camera to get a clear view of the submerged uranium slug. Light from a coaxial strip of slug surface is focused through a narrow slit in the camera shutter onto slowly moving film. Since the slug is being rotated in step with the film, an optically flattened image of the "unpeeled" surface is obtained.

DO IT YOURSELF TIME-GAMMA CHARTS

Morgan & Morgan, Inc., Publishers, of 110 Park Avenue, New York 17, N. Y. are offering blank charts which the precision-minded film processor can use to plot his own time-gamma curves for various temperature conditions.

These blank charts, illustrated below, are identical in form to the ones shown in the "Photo-Lab-Index." They are available at $1.00 for 25 charts, postpaid from the publishers. Full instructions for use are printed on the back side.